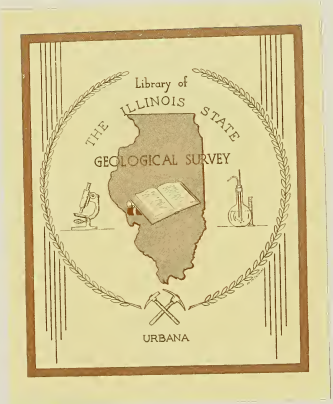

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STATE OF ILLINOIS
ADLAI E. STEVENSON, *Governor*
DEPARTMENT OF REGISTRATION AND EDUCATION
C. HOBART ENGLE, *Director*

DIVISION OF THE
STATE GEOLOGICAL SURVEY
M. M. LEIGHTON, *Chief*
URBANA

CIRCULAR NO. 181

MINERAL RESOURCE RESEARCH AND ACTIVITIES OF THE STATE GEOLOGICAL SURVEY, 1951-1952

BY

M. M. LEIGHTON, *Chief*

Preprinted from the Annual Report of the Chief to the Director,
Department of Registration and Education,
for Fiscal Year 1951-1952

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1952

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Figure 1.

The Natural Resources Building, on the University of Illinois campus, houses the offices and laboratories of the Geological Survey and the Natural History Survey Divisions of the Department of Registration and Education. The central unit of the

Dr. M. M. Leighton

MINERAL RESOURCE RESEARCH AND ACTIVITIES

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Buried treasure speaks to our imaginations of pirate gold, cryptic aps, and daring adventure in by-gone days. Illinois' great buried treas- re is not gold or jeweled diadems but coal, oil and gas, fluorspar, zinc nd lead, rock, clays, silica sand, and that homely commodity so essen- al to life and progress—water. The maps which help locate this treas- re are not old parchments buried under tree roots but geologic maps nd cross sections, prepared with great care in the offices and labora- ories of the State Geological Survey and made available to anyone esiring them. The treasure was not buried by human hands just years go but was laid down by natural processes millions and millions of ears ago—before human hands existed. Only the life-giving fresh water as entered the ground since man can remember. Even the rich soils hich blanket most of Illinois and yield its valuable crops owe their rigin to geologic processes. They have developed on earth marterial ansported from areas to the north and spread out over Illinois acres y the glaciers which covered the region during the Great Ice Age,

and by glacial winds which laid a widespread blanket of loess (dus This has rightly been called the greatest real estate transfer of all tin

But all this rich treasure would lie buried still were it not for wh man's ingenuity, industry, and inventiveness. The citizens of Illin are fortunate in having a legislature which years ago created and h since maintained a Geological Survey to discover, study, and help d velop the mineral wealth of the State which, in 1951, amounted more than half a billion dollars, distributed as follows:

Coal	$222,222,000
Oil and gas	175,000,000
Clay and clay products	55,000,000
Limestone and dolomite	19,586,000
Cement	16,029,000
Fluorspar	9,295,000
Silica sand	4,462,000
Sand and gravel	9,887,000
Zinc and lead	13,057,000
Lime	4,020,000
Ground silica	2,050,000
Mineral wool and other minerals	190,000
	$530,798,000

In addition to the above, the value of minerals processed in Il nois, though for the most part mined elsewhere, amounted to $44 000,000. These include pig iron, coke and by-products, slab zinc, s furic acid, and others. Of significance also is the fact that minerals a mineral products accounted for 52.8 per cent of the revenue freig originating in Illinois in 1951. Thus the combined value of miner produced and processed in Illinois in 1951 totaled nearly a billi dollars.

Organization and Duties

Geological investigations, sponsored by State Government, we first undertaken in Illinois as long ago as 1851, but they were, of nec sity, generalized in character and of brief and intermittent duratio The State Geological Survey in its present form was organized in 190 and fundamental work of ever-increasing scope and sharpness has be in progress continually since that time. The Survey is charged with t responsibility of securing and distributing information on the miner resources of the State. Research and investigation of a high scientif order is carried on both in the field and in the laboratory, and clo contact is maintained with industries with respect to modern tec

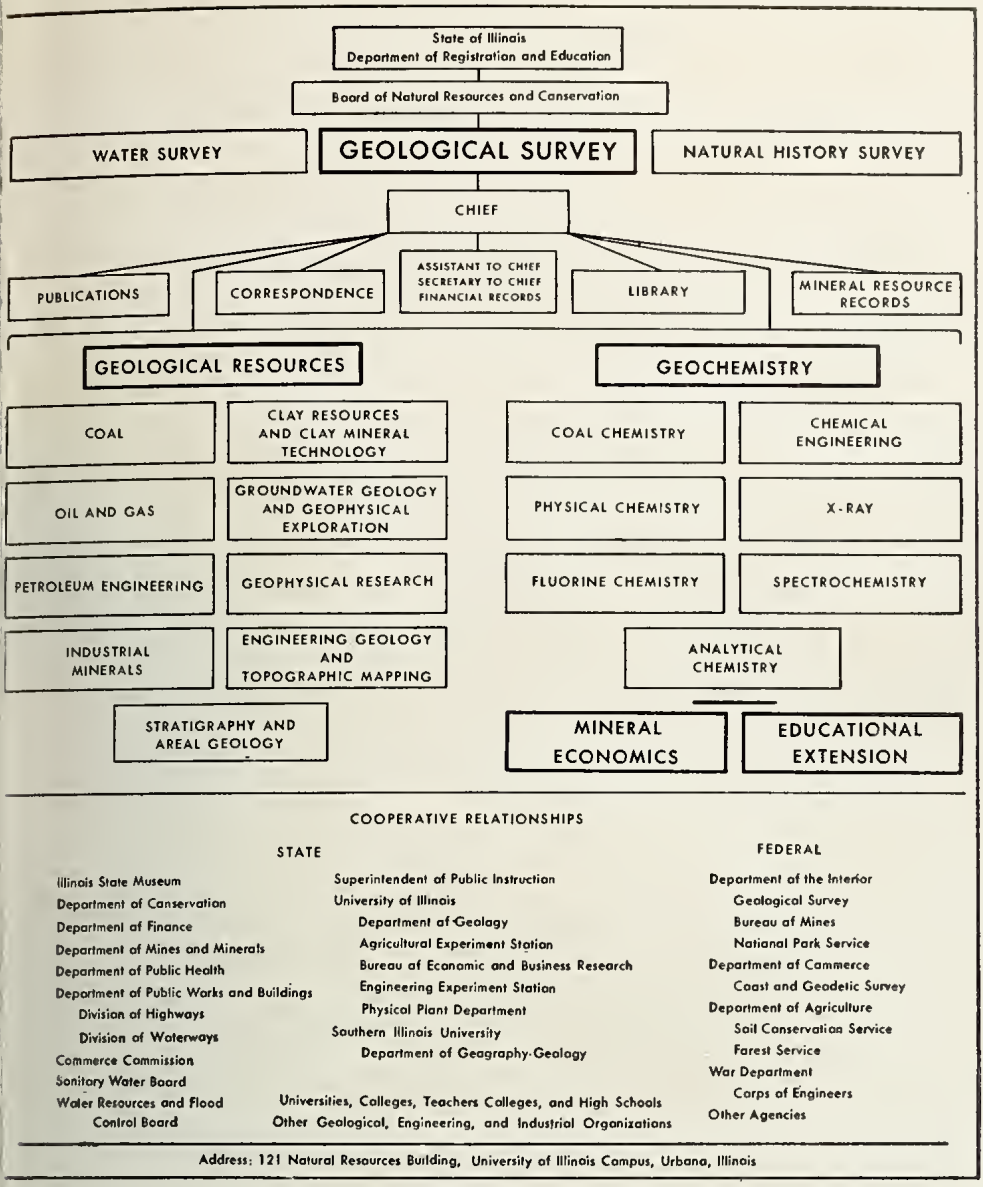


Figure 2.

Organization chart.

ological developments and their needs. Through letters and personal nferences and its many publications, the Survey provides accurate in-rmation on the State's mineral materials and products to landowners, oducers, manufacturers, consumers, and interested citizens.

The Survey's organizational pattern, shown diagrammatically in igure 2, is designed to coordinate research in varied but closely re-ted fields in order that the fruits of its efforts may be well rounded nd rooted in firm scientific soil. In 1951, its scientific and technical

staff included 49 geologists, 20 chemists, 7 engineers, a mineral econ mist, 2 physicists, editors, a librarian, a photographer, and more th 25 specially trained research and technical assistants.

The Natural Resources Building (Figure 1), in which the Survey research is carried on, was erected on the University of Illinois campus in Urbana in 1940 and enlarged in 1950. In it the Geological Surv has 40 laboratories equipped with the most modern scientific apparat for geological, chemical, and physical research; X-ray and spectrograph photography; and administrative and research offices. A separate buil ing (Figure 3) provides facilities for large-scale experimental wo on the commercial feasibility of processes developed in the Survey laboratories.

Financial Statement

The following is a statement of funds available and expenditur for the fiscal year beginning July 1, 1951, and ending June 30, 195

The amount appropriated to the State Geological Survey for tl biennium beginning July 1, 1951 and ending June 30, 1953 was follows:

Personal Services:	
Regular Positions	$1,297,200
Extra Help	36,190
Contractual Services	34,200
Office Expenses:	
Postage	6,500
Other	3,300
Travel	37,000
Commodities	71,300
Stationery, Printing and Office Supplies	62,000
Equipment	19,700
Topographic Surveys	62,500
Employer Contributions to University Retirement System	28,830
	$1,658,720

The actual expenditures and estimated expenditures on contrac through the year ending June 30, 1952 were distributed among the fo lowing activities:

Coal (Geology and Chemistry)	$117,692
Oil and Gas and Petroleum Engineering	54,860
Industrial Minerals (Geology and Chemistry)	46,682
Clay Resources and Clay Mineral Technology	13,867

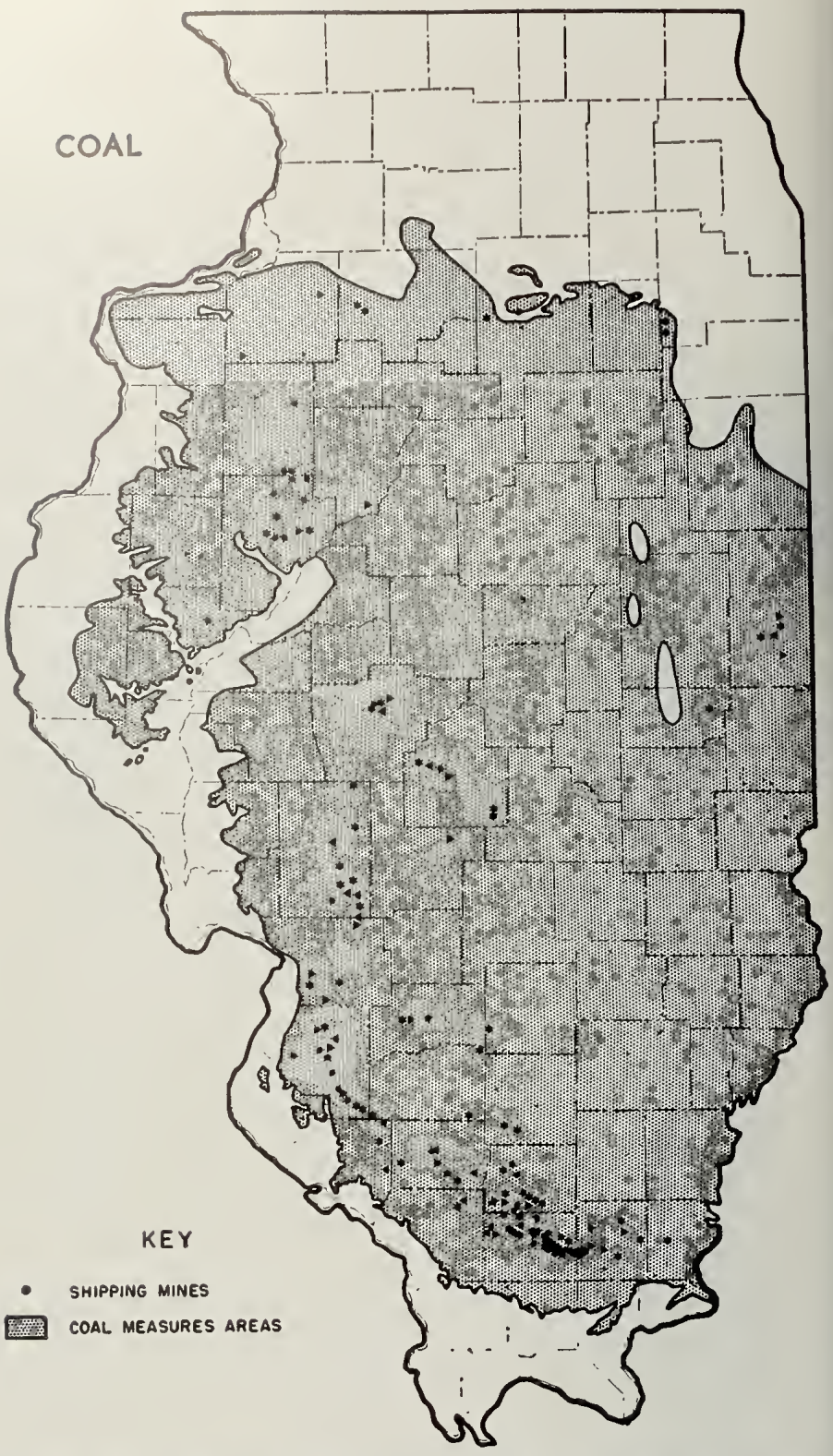
Fluorspar—Fluorine Chemistry	13,910
Groundwater Geology and Geophysical Exploration	44,718
Engineering Geology	7,833
Topographic Mapping	23,294
Areal Geology and Paleontology	66,437
Analytical Chemistry	55,934
X-ray	8,978
Physics	10,032
Mineral Economics	17,238
Educational Extension	13,486
Mineral Resource Records	25,703
Library	10,233
Publications (including printing)	35,914
Geological and Geochemistry Administration	28,868
General Administration, including Chief's Office, Financial Records, Correspondence Files, General Information Office, Clerical Services, Technical Supplies, Postage, Retirement, and some Contractual Services	119,109
Other Technical Services, including Photography and Equipment Design	19,375
Automotive Service	11,211
	$745,374

RESEARCH ACTIVITIES

Coal

Illinois produced 54,870,000 tons of coal in 1951, ranking fourth n the nation. Three mining operations (one each in Macoupin, Chrisan, and Saline counties) were abandoned during the year, having eached their economic limits of production, but new developments ave taken place—two slope mines in Williamson and Randolph counes, and a large strip mine southwest of Harrisburg in Saline County which will offset the loss from mined-out areas. New markets can e anticipated from the proposed steam generating plants of the Tenessee Valley Authority, the steam power plant now under construcon by Electric Energy, Inc., Joppa, the Ordnance Plant at Newport, ndiana, and others, and insure increasing demand for Illinois coal.

1. *The search of new workable coal beds* of commercial importice is a prime responsibility of the Illinois coal industry if it is to ntinue to meet ever-increasing demands for this valuable resource



More than half of Illinois is underlain by the Coal Measures. Dots sho locations of shipping coal mines as of 1947.

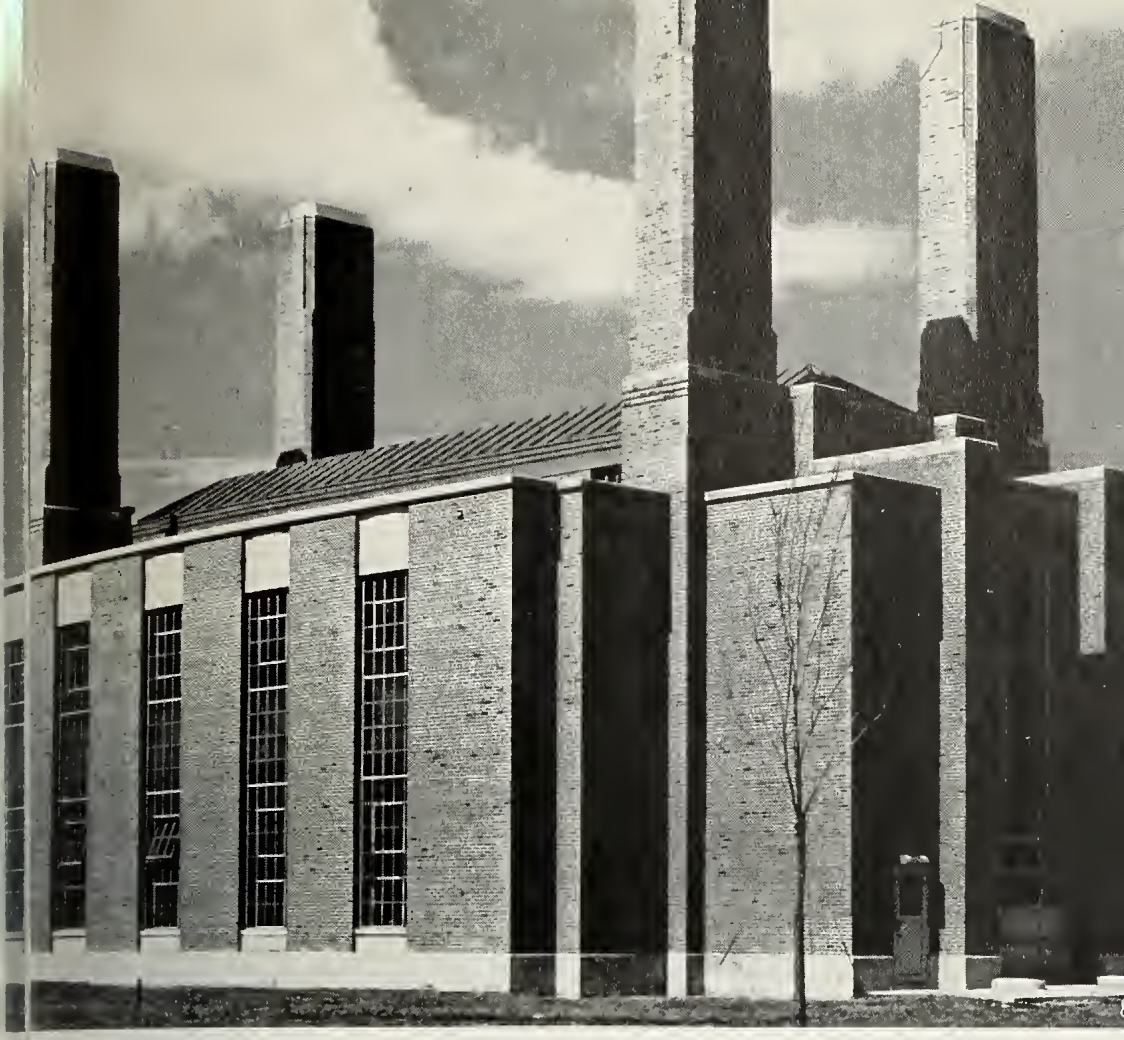


Figure 3.

The Geological Survey's Applied Research Laboratory where semi-plant-scale experiments work toward improved products from Illinois mineral resources.

and to maintain its present significant contribution to the coal output of the nation. The Geological Survey renders invaluable assistance to the exploration carried on by the coal industry by assembling records of drilling throughout the State, interpreting diamond drill tests made by the operators, evaluating areas for prospecting, and furnishing information on the rank and quality of the coal. In no other one place is there so complete a collection of data as in the Survey files; Survey geologists are continually engaged in research to determine the position, extent, character, availability, and quantity of our coal resources. During the past year a report on the coal resources of Wabash County has been revised and edited for publication, and work has been in progress on reports covering Jasper County and the Cottage Grove fault zone of Gallatin County. Diamond drill cores totaling 30,000 feet have been logged from test holes drilled in Christian, Sangamon, Williamson, Saline, Gallatin, and Douglas counties, Illinois, and in Union and Webster counties, Kentucky.

Information developed in the course of these studies is also of great value in the search for underground geological structures favorable to the accumulation of oil and gas. A significant illustration of this is the fact that a member of the Survey's Coal Division received the annual President's Award given by the American Association of Petroleum Geologists to the scientist under 35 years of age who has written the most outstanding publication in the literature of petroleum geology for a report he had prepared on "The Mississippian-Pennsyl-

One of Illinois' large modern coal mines, near Taylorville.

vanian Unconformity in Southern Illinois" (Illinois Geological Survey Report of Investigations 152).

2. *The special inventory of coal resources* undertaken at the request of the National Bituminous Coal Advisory Council of the Federal Government in accordance with their adopted plan as recommended by the Chief of the Illinois Geological Survey for inventorying the nation's coal reserves is nearing completion. The report will show coal resources of Illinois in four classes of occurrence: Class IA, proved; Class IB, probable; Class IIA, strongly indicated; and Class IIB, weakly indicated. It will also show coal classified in terms of thickness at steps of 28, 42, 54, 66, 78, 90, 102, 114, 126, and 132 inches of thickness. These very complicated data have been entered on IBM cards and great pains have been taken to design tabulations which will present the information in the most useful and effective manner for publication.

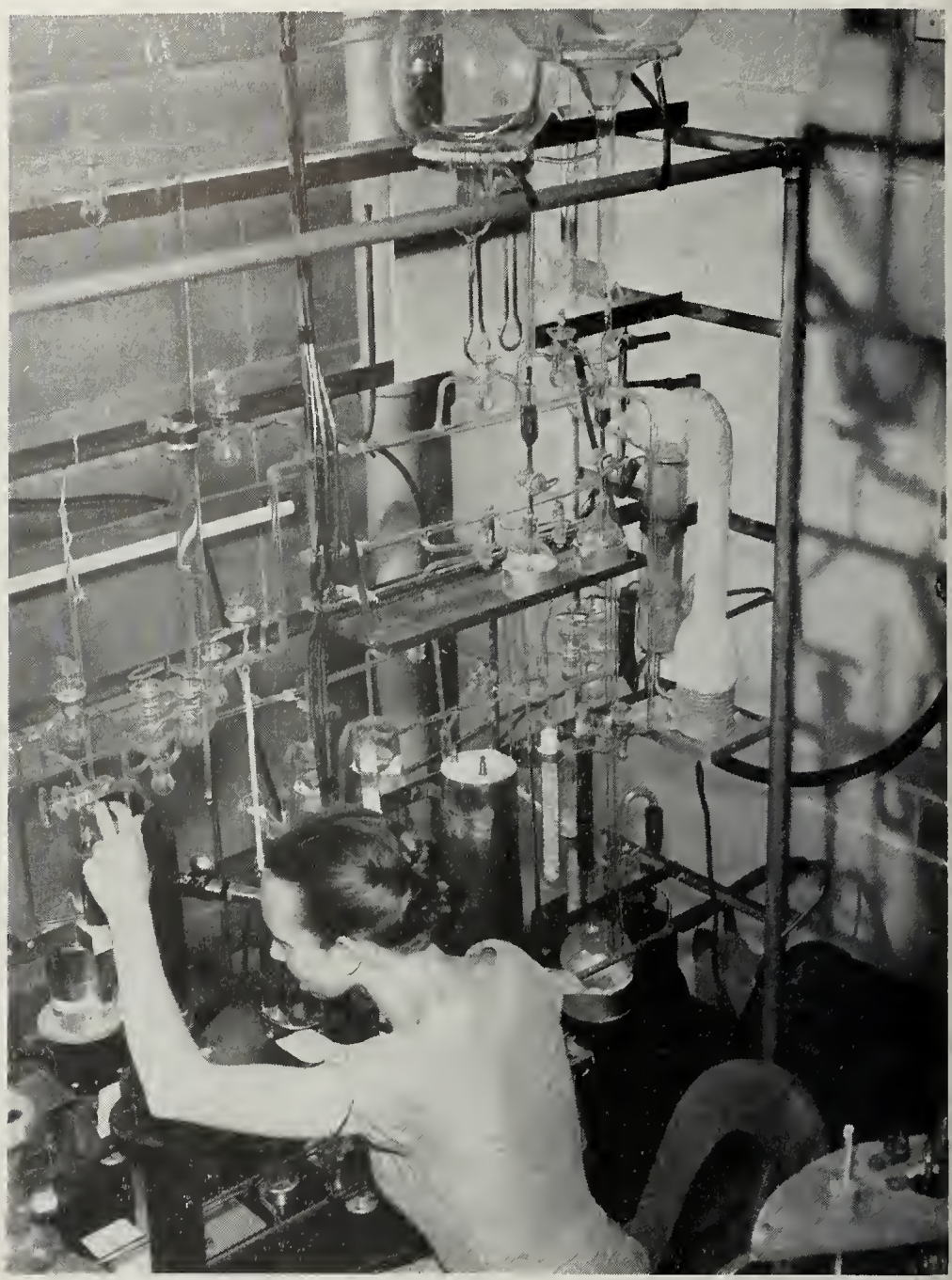
3. *Maps of mined-out areas* prepared in connection with the above inventory of coal resources have been transferred to tracing linen so that copies may now be made available to the public for the cost of blueprinting.

4. *The use of Illinois coal in the manufacture of metallurgical and foundry coke* has resulted directly from investigations carried on by the Geological Survey in its Applied Research Laboratory. In 1943 when this research was first undertaken as a War Production Board project to reduce, if possible, transportation of coking coal from eastern fields to the midwest during the war period, no Illinois coal had been so used. The following year Illinois coal up to 60 per cent of the coal blend was introduced in the coke plant at Granite City, Illinois. This use has increased both here and in other plants in the upper Mississippi valley area until in recent years the amount of Illinois coal used in the manufacture of metallurgical coke has averaged about a million tons per year.

Continued experimentation has been in progress to extend the amount of Illinois coal that can be effectively used in coking blends and to test the coking properties of different coal seams from various areas in the State. The major steel and coke companies of the St. Louis and Chicago areas have shown an active interest in the work, and very substantial additions to the coke ovens under construction in these areas create an additional potential market for Illinois coking coals.

The pilot oven of 500-pound capacity which was used by the Survey for all this work was designed and constructed by members of the Survey's Chemical Engineering staff and has proved so efficient that many requests for blueprints of its design have been received and identical installations have been made in many plants in the United States and in foreign countries. During the past year two have been built by

large industrial research laboratories in the Pittsburgh area and another in Boston. The Survey is now planning the construction of a movable-wall type oven in which to test and evaluate the expansion properties of Illinois coals, technological information required by most of the large coke producers.



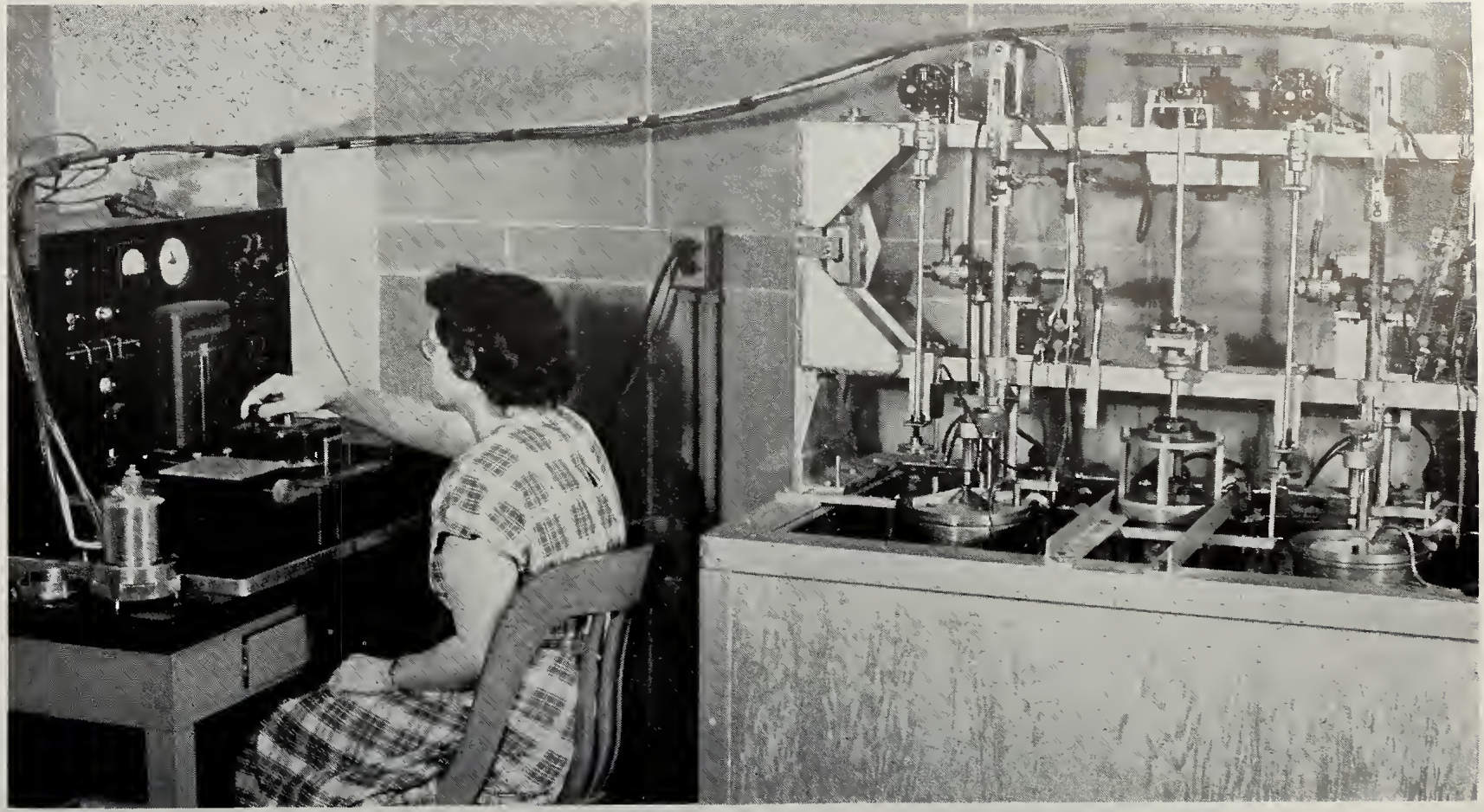
The determination of surface properties of coal is helpful in the solution of problems relating to spontaneous combustion, storage, and the use of coal in the chemical industry.

5. *Experimental work on preparation of char from Illinois coals* and its use in metallurgical coke blends as a substitute for low-volatile coals is a companion project to the coking studies described above. An experimental oven capable of continuous production of char at the rate of 30 to 60 pounds of coal consumed per hour has been constructed in the Survey's Applied Research Laboratory. The quality of char that can be derived from different Illinois coal seams is being carefully investigated and checked against commercial specifications. Work to date has demonstrated that satisfactory coke can be made from blends using char from certain Illinois coals. Thus there is some promise of another market for Illinois coals.

6. *Improvement of stoker fuels for domestic stokers* has been the goal of highly specialized investigations in progress in the Geological Survey's Applied Research Laboratory during recent years. Results demonstrating the relationships between the combustion characteristics of coal and its chemical and physical compositions as well as the effect of coal size on combustion characteristics have been published. Experiments to determine the effect on coal combustion of such things as the use of a freeze-proofing agent, storage, and heat drying of coal, are in progress using coals from different areas of Illinois. The Survey is also cooperating with Bituminous Coal Research and the Stoker Manufacturers Association in the development of a "standard" code for evaluating the performance of domestic stoker coals.

7. *The physical and chemical properties of coal* are being minutely examined to enrich and sharpen understanding of the real nature of this complex material, since more complete knowledge of this sort must inevitably lead to refinement of coal treatment, preparation and utilization, and even to the development of currently unrecognized potential uses for coal and coal derivatives in the chemical industry. Lines of investigation now in progress in the Survey laboratory include microscopic examination of coal ingredients; X-ray, thermal, and chemical analysis; and physical-chemical determination of surface area and properties of microscopic and submicroscopic particles of coal and char.

8. *The plant origin of coal* is more or less generally known but the precise determination of the character and properties of the botanical constituents of coal is a highly specialized field in which the Illinois Geological Survey has achieved national renown. Separation, identification, and evaluation of the plant particles contained in coal is done by a highly trained paleobotanist and the material so isolated is analyzed microchemically and microscopically. Work to date is throwing light on relationships between the character of plant material present in the coals and the rank of the coals and their combustion characteristics.



Duplicate determinations of the heat value of coal are part of all coal analyses made by the State Geological Survey.

9. *Mine roof studies* have been undertaken to determine the geological factors influencing the strength or weakness of coal mine roof materials, especially shales. Approximately 50 per cent of all coal mine fatalities are due to falls of roof rock and coal. Greater safety and better coal mine practice will result from improved roof control. Fifteen underground and five strip mines have been observed to date and samples collected. Field investigations are being continued, with most major mines operating in No. 6 coal to be studied ultimately.

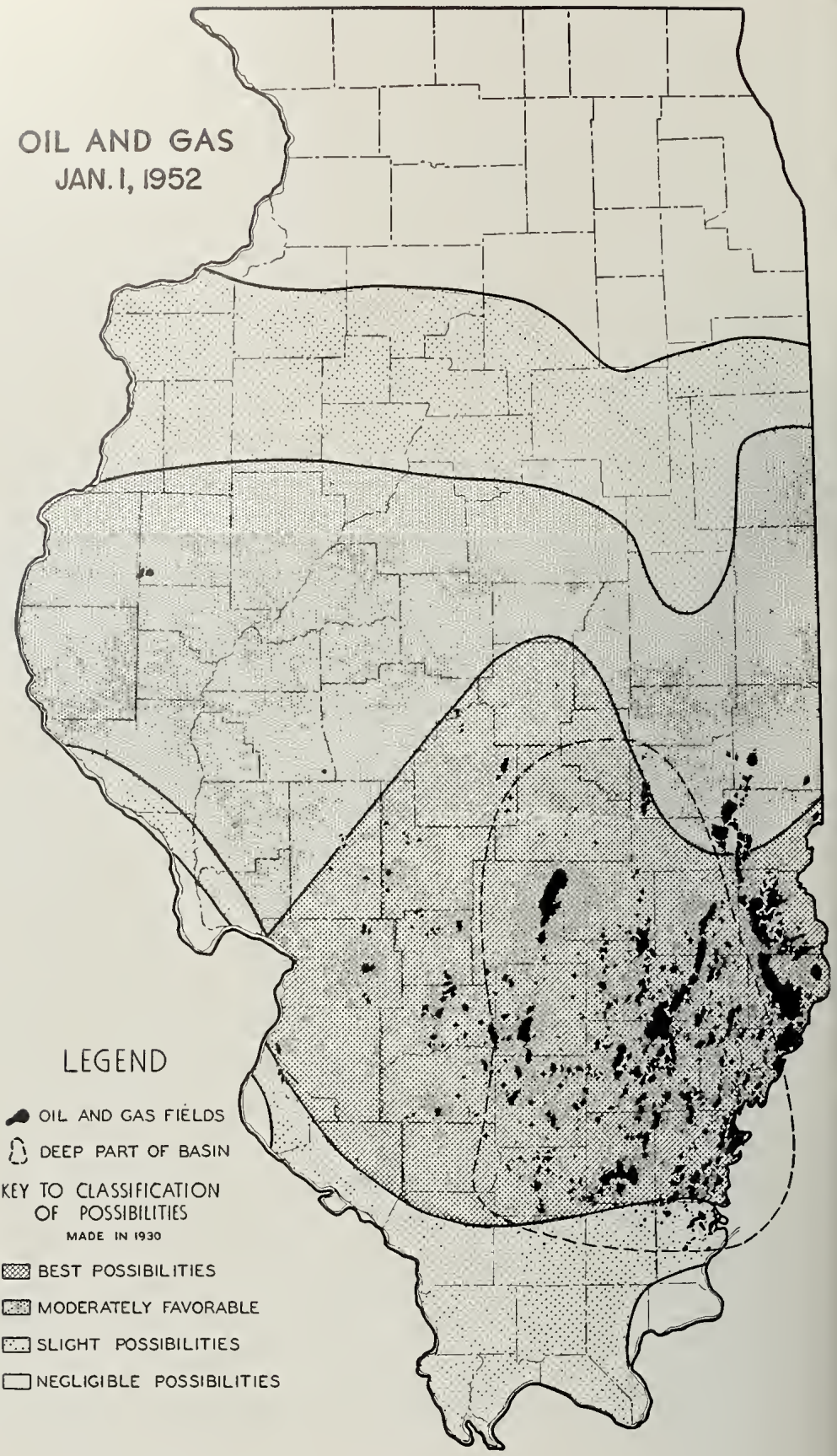
10. *Sampling and analysis of coal* purchased by the State for its various institutions is done by the Geological Survey. A truck equipped for taking samples and preparing them for analysis makes the round of the 31 institutions which use coal for boiler fuel, and a member of the Survey's chemical engineering staff keeps the engineering staffs of the State institutions informed on sampling and preparation methods. During the year covered by this report 330 samples have been received and analyzed.

Oil and Gas

During 1951 Illinois produced 60,244,000 barrels of oil. Proved reserves in the State increased from 615,700,000 barrels as of December 31, 1950, to 692,700,000 barrels as of the end of 1951. In the 12 months ending May 1, 1952, 43 new pools, 56 extensions to old pools, and 25 new "pay sands" were discovered. During the past year also a new depth record was set for Illinois oil-well drilling: a hole in the New Harmony field in White County penetrated to a depth of 7,682 feet. It has been plugged back to produce from a shallower depth.

11. *Finding more oil* is critical to national welfare to sustain defense activities as well as normal industrial and civilian well being. Oil and gas and their products are needed on our farms, in our cities, in our large industrial plants, on our highways, in the air, and on the seas. The petroleum industry searches unceasingly for new pools or "pays". The State Geological Survey assists in this tireless search by making available to all the immense amount of information in its possession. Hundreds of thousands of well records and samples of drill cuttings and cores are in its files. Members of its scientific staff study, interpret, and correlate these records; prepare maps, cross sections, and reports; answer inquiries by letter, telephone, and personal conference; and help in every possible way to guide and inform operators, landowners, and interested citizens.

12. *Geologic studies of special areas* or formations are continually in progress. A detailed report is being compiled on the geology and oil resources of the Centralia area and will contain structure and thickness maps and cross sections of great interest to oil geologists. A report


OIL AND GAS
JAN. 1, 1952
LEGEND
OIL AND GAS FIELDS
DEEP PART OF BASIN
KEY TO CLASSIFICATION
OF POSSIBILITIES
MADE IN 1930
BEST POSSIBILITIES
MODERATELY FAVORABLE
SLIGHT POSSIBILITIES
NEGLIGIBLE POSSIBILITIES

on the Waltersburg sandstone oil pools of the lower Wabash area in Illinois and Indiana was completed and published during the past year. A structure map of Christian County is in preparation.

13. *Oil-field brines* are receiving particular attention. A report based on approximately 200 samples of oil-field brines collected by staff geologists and analyzed in the Survey's chemical laboratories is being edited for publication. Such information is greatly in demand by the industry because a knowledge of the dissolved mineral content or brines is extremely important in the correct interpretation of electric logs and in other considerations.

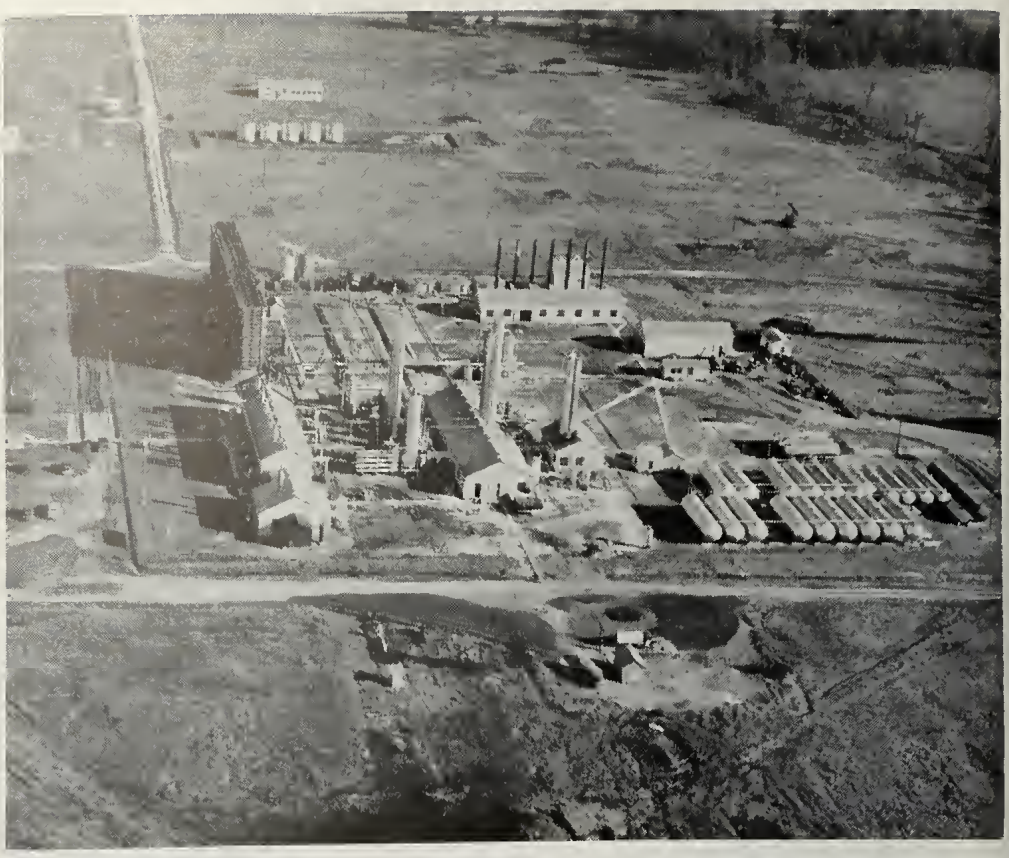
Oil-field brines have also been analyzed for radioactivity. About 55 samples have been analyzed to date and none has shown significant radioactivity. This work, however, will continue.

14. *Periodic reports.* Mimeographed reports on drilling activities throughout the State are prepared and issued each month. Nearly 500 of these reports are distributed monthly on a subscription basis in addition to orders for individual issues.

Development maps on a scale of 2 inches to the mile have now been prepared for 47 areas (each covering 9 townships) and maps of two new areas are currently in preparation. These maps show the locations of all tests and procedures and are revised every three months. A total of over 2,100 such maps were sold during the past year.

15. *Statistical reports on oil and gas development* in Illinois are compiled each year, published by the American Institute of Mining and Metallurgical Engineers, and simultaneously reprinted by the Survey. Publication of these reports has been uninterrupted since their inception in 1933 and they comprise a very valuable unbroken record of activities relating to oil and gas in Illinois during the period of 19 years.

16. *Free information service* of great value to professional geologists, operators, and landowners alike is rendered by the entire staff of geologists in the Survey's Oil and Gas Division. Information is given by letter, over the telephone, and in personal conferences, and vitalizes the Survey's assistance in the development of the oil resources of the State. Approximately 1,200 such special requests for information were handled during the year. Many of these required a review of all pertinent information in the Survey's files and the presentation of this technical data in a form comprehensible to the inquirer. The extent to which the Survey is called upon to render this service is eloquent evidence of the awareness of Illinois citizens of the help the State Geological Survey can give them.



Gasoline and repressuring plant of The Texas Company at Salem, Illinois.

Petroleum Engineering

Of great importance in developing our mineral wealth is the most complete extraction economically possible of oil from the natural reservoirs underground. In order that the Survey might be in possession of more comprehensive engineering data and be better able to assist in the solution of this and other related problems, a separate Division of Petroleum Engineering was organized in February of 1951. Two experienced petroleum engineers are giving their full attention to these matters.

17. *Secondary recovery of oil* (whereby oil remaining in the rock after natural flow and pumpage have declined below the limit of economic production is forced out of the reservoir by artificial means) is receiving critical attention by the industry and accounts for an ever-increasing fraction of the State's total oil production. One method of such recovery is water flooding, which was introduced in Illinois a few years ago largely as a result of the Geological Survey's recommendation. A comprehensive report prepared under the direction of Survey petroleum engineers in conjunction with their participation in the work

of the Interstate Oil Compact Commission and published during the past year reveals that there were 14,000 acres being flooded by controlled methods in Illinois at the end of 1950 or about 3⅓ per cent of the total productive acreage in the State. These water flood operations produced 3,000,000 barrels of oil in 1950 or about 5 per cent of the State's production for that year. It is estimated that approximately 27 million barrels of oil have been recovered by this method since it was started. The full importance of this method of oil recovery in Illinois may be realized from the fact that the Survey's Petroleum Engineer has recently estimated that the ultimate secondary oil recovery in Illinois will be at least 800 million barrels.

The problems of water flooding require several lines of physical and chemical studies, some of which are concurrently under way or about to be undertaken in the Survey's laboratories. One such study concerns the relationship between the rate of water injection in an individual well and the average permeability of the formation being flooded. Another study being planned will deal with the physical properties of Illinois crude oils (gravity, viscosity, and interfacial tension with water) and the effect of water flooding on the physical properties of crudes. The current study of the clay mineral content of the various oil sands will be enlarged to include the effect on fluid permeability and transmissability of oil when waters of different compositions are used. Certain clay minerals swell when wet; this phenomenon unrecognized or unchecked could hamper the effectiveness of any water flooding project.

18. *A new and important activity* of the oil and gas and utilities industries is the storage of natural gas and liquefied petroleum gases (bottled gas) underground in suitable rock formations. Underground storage of large quantities of such petroleum products at points near the consuming areas is of tremendous importance to our economy and standard of living. In the winter months gas shortages can be avoided and great savings in steel can be realized because the rocks themselves are the containers.

Requests made of the Survey in recent months involve two projects by major gas pipeline companies for the storage of billions of cubic feet of natural gas underground and several projects by major oil companies involving the storage of millions of gallons of liquefied petroleum gases. A great deal of accurate geologic and engineering data is required to determine the feasibility of each project and the Geological Survey has cooperated effectively in furnishing the type of information which could be secured from no other single agency.

Airplane view of Illinois Clay Products plant in northern Illinois.

Clay and Clay Products

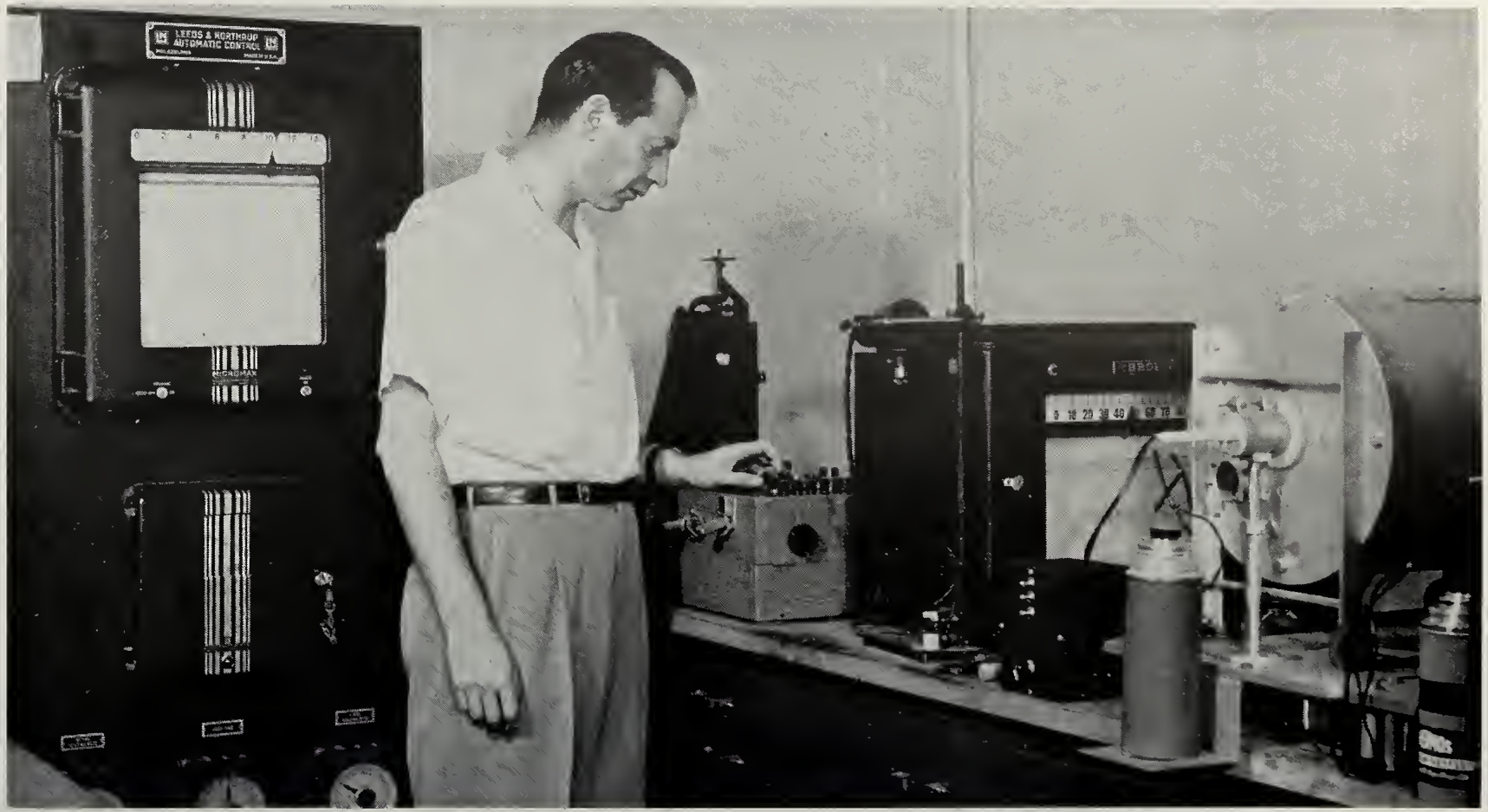
The value of clay and clay products produced in Illinois in 1951 amounted to about $55,000,000, an increase of 12 per cent over 1950 production, made up as follows: structural clay products (common, face, and paving brick; drain, structural, and ornamental tile, etc.), $19,610,000; refractories, $11,687,000; and whiteware and pottery, $22,398,000. Approximately 10 per cent of the brick manufactured in the entire United States is produced in Illinois.

19. *Survey's work outstanding.* The fact that ceramic clay is the foundation of one of the State's most valuable mineral industries led the Geological Survey, some 20 years ago, to inaugurate a comprehensive program of fundamental research on the physical, chemical, and structural character of the mineral composition of clay. Subsequent results have been of such significance both from the standpoint of practical application to industrial problems and of science that the Survey's work has become known throughout the world, and visitors come literally from the four corners of the globe to visit the Survey's laboratory and observe its research techniques.

20. *Information of great practical value* comes from the determinations made in the Survey's laboratory. Research has revealed that clay is not a simple homogeneous substance occasionally containing impurities but is actually a complex combination of various clay minerals. These clay minerals differ from each other in their behavior under varying conditions of temperature, pressure, moisture, etc., to which they may be subjected in commercial processing. Therefore the predominance of one or the existence of another even in small quantities in any given clay may affect the end product.

The Survey's research facilities for this highly technical work comprise powerful petrographic microscopes, special laboratory ovens for thermal analysis, X-ray and spectrographic equipment, an ultrasonic vibrator, and extrusion and compression apparatus. Through the use of these facilities by its technical and scientific staff and by keeping in close touch with the clay industry and its technological developments, the Survey has come to be an effective agency in helping to develop the clay resources of the State.

21. *Systematic collection of data* on the clay and shale resources of the State is continuous. Field sampling and laboratory analysis as described above add each year to the already large assemblage of technical information which enables the Survey to advise and assist operators in locating deposits which will meet particular specifications and to give informed consideration to the various problems of the ceramic industry as well as to geological engineering problems relating to mining, highway and dam construction, etc.



Differential thermal analysis apparatus helps to identify minerals which undergo physical changes at elevated temperatures.

During the past year a special report has been in preparation on the resources and properties of the high-grade clays in western Illinois. This area contains some light-burning ceramic clays which are of interest to the ceramic industry in that part of the State and also to the structural clay products industry in other parts of the State. Study of the field occurrences and the laboratory testing of samples have been completed and chapters on Adams, Brown, Calhoun, Cass, Fulton, Greene, Hancock, Henderson, Madison, and McDonough counties have been written.

22. *The bonding properties of clays* have been the subject of intensive investigation by the Survey in cooperation with a leading clay products company and the Engineering Experiment Station of the University of Illinois. One extremely significant result of this research has been the recent development by the company of a revolutionary new type of refractory fire brick used primarily as a lining for steel ladles. These brick are unfired before being placed for use and owe their mechanical strength to a chemical bond which develops after treatment and from firing in place by the hot metal and slag with which they come in contact. Elimination of the firing operation in a kiln results in a brick of precise dimensions without shrinkage and warpage, such as is encountered in conventional firing procedures. Inasmuch as the refractories industry is the backbone of the steel industry, any such developments are of substantial importance in increasing the output of steel production.

23. *Soil mechanics of earth material*—a significant factor in projects such as the building of dams, the erection of heavy industrial installations, and the construction of airfield runways—are directly related to their clay mineral content. Using physical, chemical, and X-ray techniques, the Geological Survey has been conducting special investigations of the behavior of different clay minerals under varying conditions of load, moisture, etc. A new confined compression machine built in the Survey shop is being used to determine the compressibility of reworked clay minerals with known water content in order to gain more knowledge of the sensitivity of the various clay minerals during compaction of sediments or clays under load.

To assist in determining which clay minerals are most likely to be unstable during and after the construction of dams, buildings, highways, etc., it is necessary to collect and study samples of formations known to be unstable. During the past year construction engineers have sent to the Survey some 49 samples of clay and shale which have proved unstable during and/or after construction. Thirty-six of these samples have been studied to date. The clay mineral montmorillonite has been found in all of them and another clay mineral similar to it has been present in about half of them.

The adaptability of clays to modern ceramic techniques is tested in part with this laboratory-size brick extrusion machine.

While conclusions can be drawn only after careful evaluation of sufficient data, it is apparent that the Survey's studies are developing knowledge which will help in the prediction of the behavior of earth materials and in preventing costly engineering errors.

24. *The cause and nature of efflorescence on brick* is an unsolved problem of the brick industry. The Geological Survey is conducting special chemical investigations to determine, if possible, the relationships between this unsightly defacement which so frequently develops on brick and the composition of the brick and mortar used in the construction of masonry walls.

Rock and Rock Products

More than 200 plants in Illinois produced rock products valued at more than $52,000,000. These include limestone and dolomite, cement, silica sand, ground silica sand, and sand and gravel.

25. *Stone used for many purposes*—for building, for road materials for the "liming" of soil, for the manufacture of lime and cement,

Loading limestone in a large Illinois quarry for the production of concrete aggregate, road material, agricultural limestone, and other purposes.

X-ray equipment is used in analyzing crystal and molecular structure of minerals and in identifying them.

for flux in the steel industry, and for other industrial uses—is in continuous demand, and the Geological Survey renders valuable assistance to the industry in locating workable deposits. Field and laboratory investigations carried on through the years have developed a tremendous amount of information on the extent, thickness, and quality of the rock formations of the State, and this inventory of stone resources is continually being increased. During the past year exploratory work was carried on in Fulton County where prior to 1951 there were no limestone quarries. Though likelihood of large-scale open-pit quarrying is remote, it appears that moderate amounts of stone can be obtained and underground mining may prove economically feasible. One quarry opened during the past year is producing agricultural limestone and road rock on a commercial basis.

26. *Research on the physical and chemical nature of limestones and dolomites* is being carried on to obtain a better understanding of the changes that take place either in the weathering of stone or in the course of industrial processing. Such technical information is necessary to meet the increasing refinements of commercial specifications.

Studies currently in progress on the soluble salts in limestone and dolomite have economic application in connection with lime burning, the physical properties of lime, the uses of limestone and dolomite powders, and the weather stability of building stones and concrete aggregate. Thirty samples of Illinois limestone and dolomite have been subjected to physical, chemical, and X-ray analysis during recent months.

Systematic sampling and analysis of the commercial limestones of the State is also in progress. Analysis of samples taken bed by bed in a quarry in Rock Island County during the year revealed a bed of workable thickness which has potential specialized use in the chemical industry. Investigation of a quarry in LaSalle County made at the request of the operator showed great variety in purity of the different layers comprising the deposits. The information will enable selective quarrying to produce agricultural limestone from those strata best suited for this purpose and to utilize less pure stone for other purposes.

The kind and amount of trace elements (such as zinc, copper, manganese, boron, cobalt, and iodine) in limestones and dolomites used for agricultural limestone and mineral feeds for stock is increasingly significant in connection with plant and animal nutrition. The Survey has initiated research into this subject and has collected and prepared for spectroscopic examination some 48 samples from a quarry in Vermilion County so selected as to yield information on the constancy of trace-element content of the deposit both laterally and vertically.

Testing the abrasiveness of southern Illinois and northern Illinois silicas helps to evaluate their usefulness.

27. *Agricultural limestone for the enrichment of soils* is in great demand and about 3,500,000 tons of stone for this purpose was produced in Illinois in 1951. The Survey tests free of charge samples of stone submitted by operators and landowners. There were numerous requests last year from county farm advisers and others for the map prepared by the Survey showing in detail those areas in which limestone of more than 3 feet in thickness crop out. Much interest has recently been aroused in the magnesium content of agricultural limestone and this map has been most helpful in furnishing the desired information.

28. *Southern Illinois contains attractive building stone* very similar in appearance to the widely used Crab Orchard quartzite from Tennessee. The Survey has collected a suite of samples from a southern Illinois quarry for display purposes and the stone has received favorable comment from the Small Homes Council of the University of Illinois and others.

29. *The abrasive properties of southern Illinois silica* have received particular attention by the Survey. Special testing equipment constructed in the Survey shop which determines the degree of abrasiveness of grinding materials has been most useful in assisting producers to evaluate their products.

30. *Minerals in Illinois sands.* Since some of the fine-grained sands of Illinois contain small quantities of heavy minerals and since some of these minerals, notably ilmenite and zircon, are of considerable economic importance, an investigation was made this past year of 19 samples of fine-grained Illinois sand. The principal heavy minerals found were ilmenite, garnet, and magnetite. Maximum amounts were found in the dune sands near Zion City, Lake County, and minimum amounts in the Cretaceous sands of extreme southern Illinois, and quantities ranged from 23.6 per cent to 0.1 per cent by weight. Ilmenite and magnetite are the only heavy minerals occurring in sufficient amounts to be of possible commercial importance, but in general the recovery of heavy minerals from Illinois sands is probably not economically feasible at the present time.

A large company outside Illinois has recently made inquiry regarding undeveloped industrial minerals in Illinois. The Survey's suggestion that they might be interested in recovering feldspar from Illinois sands (a subject explored in the Survey's Report of Investigations 79, published in 1942) was favorably received, though no commercial development has yet been undertaken.

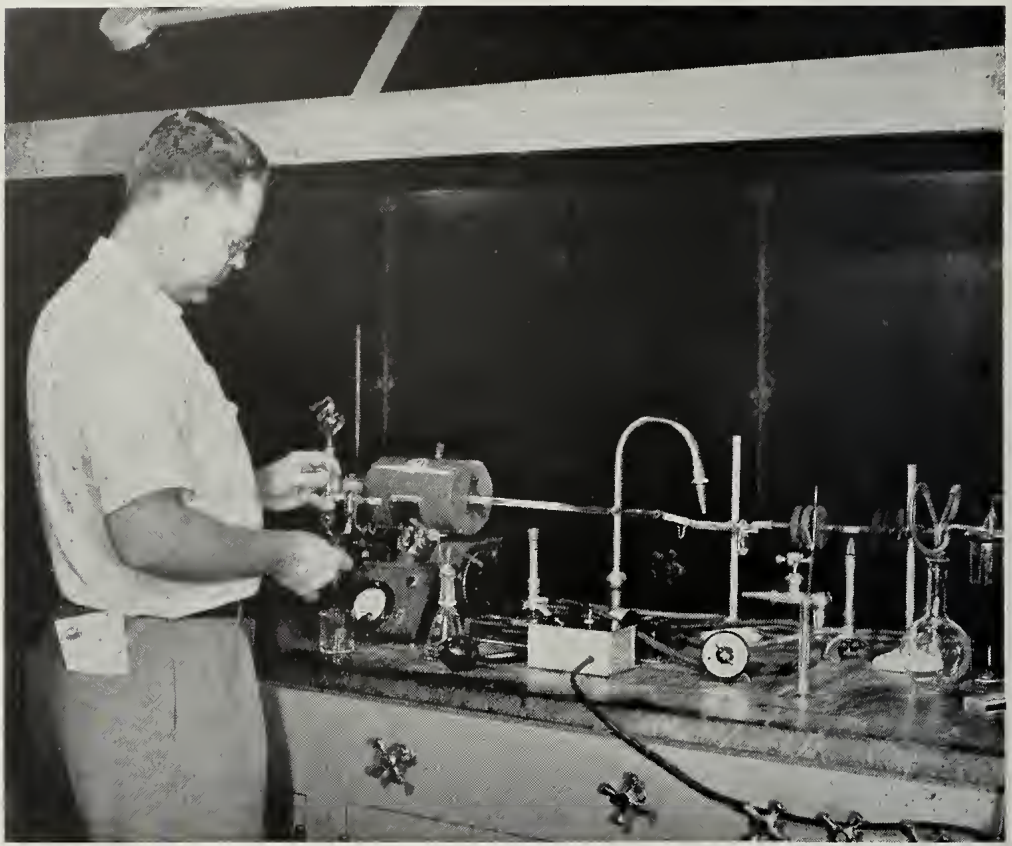
31. *The sand and gravel resources* of the State are also being investigated to help the operators and landowners find and develop workable deposits.

32. *The chemistry of silicate melts* (mixtures of lime, magnesia, alumina, and silica at high temperatures) is a project of the Survey's Geochemical Section designed to obtain fundamental information applicable to problems encountered in the ceramic industry, and in the manufacture of mineral wool, pig iron, and steel. Results obtained in experiments carried on during the past year include information on the effect of fluorspar on surface tension, a subject of considerable interest to the porcelain enamel industry.

A report on the viscosity studies of the lime-magnesia-alumina-silica system at silica-content levels of 35%, 45%, and 50% was completed and submitted for publication.

Fluorspar

Owing to the unusually heavy demands for fluorspar, hydrofluoric acid and products derived from it, the value of fluorspar produced in Illinois increased from $6,111,000 to $9,295,000, 52 per cent higher, and the tonnage rose from 154,623 tons in 1950 to 204,328 tons in 1951, an increase of 32 per cent. More than half of the spar produced



Micro-analysis of organic fluorine compounds is done in one of the Geological Survey's specially equipped laboratories

in the entire United States comes from the Hardin-Pope County area of southeastern Illinois. Formerly used almost exclusively as a flux in the manufacture of steel, fluorspar is now in demand for the ever-expanding chemical industry which uses almost half of Illinois' production in the preparation of refrigerants, insecticides, aviation gasoline, fluor-carbon plastics, in medical research, and in the development of atomic energy.

33. *Geologic investigation of the fluorspar-producing area* in Illinois has been in progress by the Survey for many years and has aided materially in the discovery of valuable deposits of this strategic mineral. Survey geologists have consistently cooperated with the operators by interpreting results of core testing and guiding exploration for extended workings. During the past year numerous requests for such assistance were received and valuable assistance was rendered. In April 1952 Bulletin 76, *Geology of the Fluorspar Deposits of Illinois*, was issued. The report is of a practical nature, contains much new material, and has a geologic map of the entire area as well as special geologic maps of the more important mining districts. Because of a long-felt need it has been warmly received by the Illinois fluorspar industry.

34. *Highly specialized research on the chemistry of fluorine and fluorine compounds* in the Survey's laboratories has received nation-wide recognition. The primary objective is to develop more diversified use of Illinois spar as a chemical raw material. Many important applications of the results of this work have already been made. An outstanding example is the fact that a rare fluorine compound produced in the Survey's laboratories contributed to the early success of the Manhattan project.

During the past year a contract has been signed with the U. S. Air Force for the synthesis of organic fluorine compounds by the Geological Survey for fungicidal testing by the Natural History Survey. The Survey has also been called upon by a branch of the Federal Government for the production of certain organic fluorine compounds which could not be secured from any other source.

Zinc and Lead

The fact that Illinois is again producing appreciable quantities of zinc and lead ore is a direct result of the Illinois State Geological Survey's field explorations in northwestern Illinois, undertaken in 1943 when wartime need for these minerals was great. The lead deposits of the Galena area (from which the town derives its name) were a critical factor in making this district a dominating influence in the early development of this part of the Middle West during and after the Civil War. Since 1900, however, rich deposits discovered and developed elsewhere led to the virtual abandonment of this old mining district. The

Survey's field work encouraged new prospecting in the area and in recent years a thriving mining industry (principally zinc, secondarily lead) has grown up. In 1951 Illinois produced 32,900 tons of zinc valued at $11,844,000 and 3,500 tons of lead valued at $1,213,000.

35. *A field office at Galena* is maintained by the Geological Survey where a small staff is permanently stationed. Survey geologists carry on active field investigation and research, study and interpret cores and drill cuttings, and assist operators and prospectors in their search for additional mineral deposits. During the past year these services included the study of 188 different prospect drillings (of which 36 contained significant quantities of mineral) and many conferences with members of the northwestern Illinois mining industry, with personnel of the U. S. Bureau of Mines and U. S. Geological Survey, and with landowners and individuals interested in zinc and lead resources. The work the Survey is doing has meant a great deal to this area, and many expressions of appreciation of its services have been received.

36. *Geological studies of mineralized zones* are in progress to determine whether or not there is a pattern of alteration of wallrock adjacent

Head frame for bringing zinc ore to the surface at a northwestern Illinois mine and plant for separating ore from waste rock.

to ore bodies. Such information properly evaluated would materially reduce the depth and amount of costly test drilling in the search for ore deposits. Studies made in the past year with respect to wallrock alteration and vertical distribution of lead, zinc, and pyrite in the strata overlying a large ore body now being mined and a comparison of the data derived with structure maps give promise of usefulness. Detailed studies in the mines of the ore bodies themselves and the preparation of cross sections showing distribution of the ore in detail are also in progress to perfect our understanding of the nature and character of the ore body.

37. *Structure mapping* done by the Survey has served as a guide to much of the prospecting that has been done in the area over the past several years. As new data are secured from drilling and mining operations existing structure maps are revised and new mapping is extended. During the past field season new structure mapping was completed in an area in the northwestern corner of Jo Daviess County.

Groundwater Resources

Water supply can spell success or failure to human enterprise on the farm or in the city. The location of groundwater resources—whether in amounts adequate for the farmer's family and stock, for the small village or town, or for large industrial plants or army camps—is largely a geological problem. The State Geological Survey, therefore, maintains a full-time staff of 8 geologists, a draftsman, and a technical assistant to study and report on the geology of groundwater resources throughout the State.

38. *Special reports* are prepared on the geology of specific localities where water is needed. These reports tell the driller or landowner what kind of rocks underlie the area, in which of them water is likely to occur and at what depth it will probably be found. During the past year 174 such reports were prepared of which 74 were for private citizens, 43 for industrial installations, 32 for municipalities, and 25 for public institutions. In addition some 52 technical and geophysical problems were handled by correspondence. Among the more significant geological studies made this year for groundwater resources were several for oil companies requiring water in large amounts for the secondary recovery of oil, one for the large petro-chemical plant now under construction at Tuscola, Douglas County, another for groundwater in the amount of 15 million gallons a day at a temperature below 55° for one of the major railroads, a restudy of groundwater possibilities at Scott Air Force Base, and a report for the State Division of Highways on groundwater possibilities at 15 truck-weighing stations throughout the State.

A small refraction seismograph is used in the field. The operator is ready to set off a small charge of dynamite by remote control. The resulting shock waves will be recorded on photographic paper and interpreted with respect to unknown geological conditions underground which bear on the solution of groundwater and engineering problems.

39. *Geological studies relating directly to groundwater resources* are continually in progress. A special study is being made of the East St. Louis area and a study of the groundwater geology of Lee and Whiteside counties has been started.

40. *Geological interpretation of results of test drilling* is made by Survey geologists through the microscopic examination of drill cuttings and the mechanical analysis of sand in order to assist drillers in the evaluation of their testing.

41. *Electrical resistivity surveys* are made to discover the location of extensive underlying gravel deposits which might carry large quantities of water. The Survey pioneered in this method of locating water supplies which has proved very effective in directing the placement of test holes and has saved much needless and expensive testing in barren areas. During the past year 39 such surveys were made, 9 for industry, 5 for public institutions, 19 for municipalities, and 6 for domestic and farm groundwater supplies. Thirteen of the surveys made for water resources have been checked by subsequent test drilling and at 11 sites adequate aquifers were found.

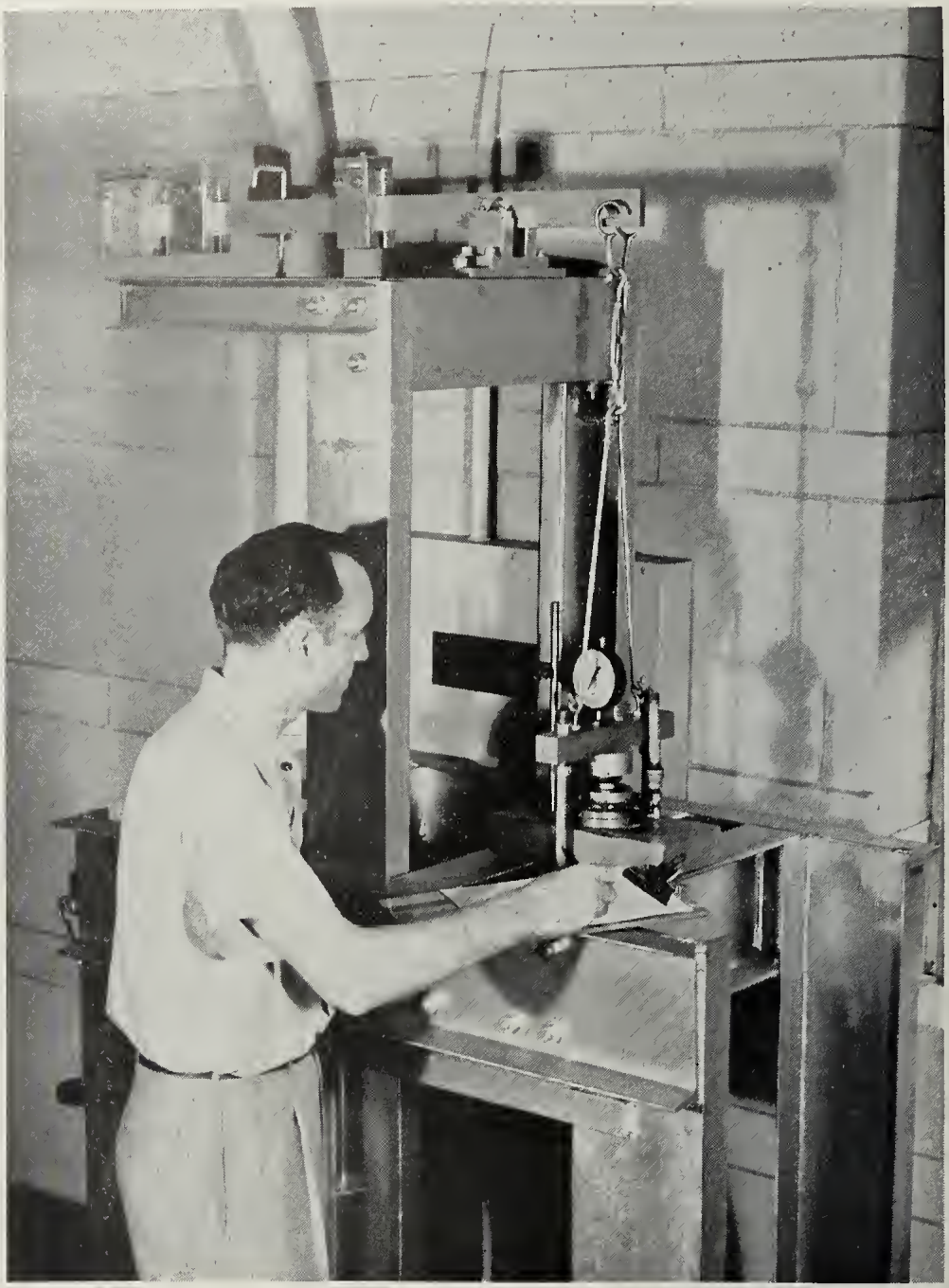
42. *Cooperation with the Illinois Water Well Drillers Association* has been continued, a member of the staff serving as executive secretary of the Association. The Geological Survey was partly instrumental in the foundation of this Association in 1927 and continues its cooperative support in order to promote the science and art of water-supply development.

Geophysical Research

43. *The use of radio wave transmission* through rock formations as a research tool was developed by the Geological Survey and made known through a Circular published in 1950. This work proved of great interest to many in the field of geological exploration and also to the U. S. Army Signal Corps, which through consultants undertook an investigation of the propagation of the electro-magnetic waves through rock formations of varying lithology. Research by the Survey is being continued.

44. *Another valuable research tool* now being used by the Geological Survey is a refraction seismograph secured during the past year. Preliminary use in the field during the past three months indicates that it will prove an effective means of determining bedrock surface in areas where that surface is completely obscured. Small charges of dynamite are exploded at shallow depth (6 or 7 feet) and the course, intensity, and speed of the waves of the miniature earthquakes so created are recorded on instruments placed at regular intervals on the surface of the ground. By painstaking interpretation of the data so recorded the position and depth of rock can be calculated.

The seismograph has been used to exceptional advantage, in conjunction with earth resistivity surveys, during the spring of 1952 in geological investigations for groundwater resources and engineering data made at the request of the engineers engaged for a large chemical plant now under construction near Tuscola in Douglas County. Exploration



The Confined Compression Apparatus is used to help determine the value of earth materials for foundation purposes.

with this instrument can help locate and trace buried bedrock valleys which can then be surveyed by electrical resistivity methods to locate water-bearing gravels.

Research will be continued on the application of seismological techniques to other types of geologic exploration.

45. *New earth resistivity apparatus* has been devised in the Survey's laboratory and construction is nearing completion. This new instrument, which will be ready for use in the coming field season, will be the smallest, most compact, and lightest thus far constructed, and incorporates the latest technological improvements.

Engineering Geology

Geological conditions materially affect the engineering aspects of problems relating to highway construction, the selection of suitable sites for reservoirs and dams, the stability of earth materials for foundations for large structures, or the character and strength of rock strata as it may affect the planning of underground excavation. The Survey's Engineering Geology Division cooperates with Federal and with other State agencies on problems of this type.

Fissures in a highway fill (left) and rupture and displacement of wing wall of culvert (right), resulting from lateral and downward movement of underlying plastic clay, on U. S. Highway 40, Clark County, illustrate one of the many problems of engineering geology.

46. *Geological assistance on engineering problems* is rendered through field and office conferences. Where necessary, earth materials are sampled and studied, and reports are prepared. During the year this type of cooperation was extended to the State Division of Highways with regard to limestone masses encountered in an excavation for the construction of U. S. Highway No. 40 east of Marshall, the sinking and

The study of cores taken from deep drill holes is an important method of disclosing the mineral resources of the State.

latcral movement of the fill at another point along the same highway, as illustrated, soil conditions along a proposcd realignment of Fedcral Aid Route No. 132 near Roxana, the geological conditions contributing to a landslide along State Highway No. 3 a few miles southeast of Chester; to the State Division of Parks and Memorials concerning the reconstruction of a dam at Dixon Mounds State Park; to the DuPage County Health Department concerning the topography, drainage, and geological conditions of an area being considered as a sitc for garbage disposal; and to the U. S. Army Ordnance Corps at the Savanna Ordnance Depot on the geological conditions in the vicinity as they might be related to possible damage to property in connection with the detonation and destruction of undesirable ammunition at the Depot.

As a matter of policy the Geological Survey confines its assistance to furnishing geologic information basic to the engineering aspect of the problems which are brought to it and thus scrupulously avoids competing with private engineering consulting practice. Such assistance is frequently requested by consulting engineers who have been engaged on problems requiring geological information for their solution. Notable examples of this type of service rendered during the past year include the underground storage of natural gas and propane, advice on the proposed damsite for Scott Field, a dam and reservoir site in Dellwood Park at Lockport, and various small lakes on private property. Numerous requests have also been received for information on depth to bedrock at many points.

Basic Research and Mineral Resource Records

The solution of many specific practical problems would be virtually impossible were it not for long-range patient research of a basic nature in geology, chemistry, and physics. Work of this type is continually in progress both in the field and in the Survey's laboratories.

47. *Rock formations lying deep underground* are studied by the microscopic examination of drill cuttings from test holes and deep wells. During the past year 7,181 samples of cuttings from oil wells, representing 36,225 feet of section, were studied, and a total of 11,979 samples from 111 water wells, representing 63,880 feet (more than 12 miles) of section, were studied. Sample study logs of the wells represented are prepared and furnished to the operators and copies are placed in the Survey's files. Information developed in this way is of inestimable value in the correlation of rock strata in connection with the search for oil and gas, coal, and other valuable mineral deposits, and the Survey is continually called upon for the interpretation of these data. The samples themselves are labeled, assembled into sets corresponding to each well logged, and systematically filed. Over a thousand such sets from as many wells were filed during the past year, bringing the total number of sample sets on file to well over 22,000.

Misroscopic study of drill cuttings reveals the nature and succession of buried strata. Work of this type is of great value in discovering mineral deposits.

48. *Accurate correlation of rock strata* rests not only on such studies as those just described but also on field examination of the formations where they are exposed at the surface, the identification of animal or plant fossils which they contain, recognition and evaluation of lithological features, and other investigations which can be adequately carried on only by highly trained geologists. During the past year special attention has been given to formations of Cambrian age, some of which are important aquifers in the northern part of the State. The Survey has been fortunate also in securing a 5-inch core from a test hole drilled to a depth of several thousand feet through formations which do not come to the surface in that part of Illinois. Detailed study of this core is particularly important at this time because of the increasing interest in the oil possibilities of deep formations.

Careful correlation studies are also of special significance in connection with the zinc and lead deposits of northwestern Illinois, buried fossil coral reefs in the search for accumulations of oil and gas around these old structures, and rock formations of lower Mississippian age which are economically important in several ways.

Special field and laboratory studies have also been made of Pleistocene deposits which are of particular significance in connection with sand and gravel production and groundwater resources.

49. *Spectrographic analysis of rock and mineral samples* identifies minute amounts of mineral substances which frequently have an important bearing on the properties and use of the materials in which they occur. The Survey has a special spectrographic laboratory for this kind of work.

50. *The Analytical Chemistry Division* of the Survey works hand in hand with the geologists, other chemists, and physicists of the staff in furnishing detailed chemical data essential to so many aspects of the Survey's work. During the past year, 2,565 analyses were made on samples of coal and coke, 146 on rock samples, 232 on samples of brine from Illinois oil fields, 114 on samples of oil and gas, and 198 analyses were run in the special microchemical laboratory.

51. *Systematic filing of research data* is of paramount importance. The lasting value of such information depends in large part on its accessibility for continued reference use. A special Mineral Resource Records Division, staffed by 8 full-time personnel, maintains active files containing over 125,000 well log records, 30,000 electric logs, some 3,500 lantern slides, 5,000 maps, and other valuable research material including manuscripts, field notes, etc. The Geochemical Section of the Survey has in its files approximately 15,750 chemical analyses which include: coal, 7,929; rock, 3,611; gas, 765; oil, 447; brine, 1,277; and micro-analyses, 923. In addition to these paper records over 22,000 suites of actual samples of drill cuttings are filed in labeled containers where they are accessible for examination and review at any time.

A part of the Mineral Resource Records room. Here is where the logs of oil and water wells and other data on the mineral resources of the State are carefully filed for ready reference.

Mineral Economics

The economic trends and competitive factors in mineral production, transportation, and marketing are critical in industrial development. Through the work of a mineral economist with a small staff of assistants to compile data for analyzing these problems, the Survey is in a position to furnish economic information desired by mineral operators, producers, manufacturers, railroads, chambers of commerce, and financial organizations throughout the State.

52. *The market outlook for sulfur recoverable from coal* was the subject of a special study made by the Survey's Mineral Economist this past year. A paper was presented at the annual meeting of the Illinois Mining Institute in November 1951 and reprinted as Circular 177.

53. *Special studies are in progress* on mineral resources in the industrial development of the Middle West and on mineral requirements of Illinois agriculture.

54. *The annual statistical report* on the Illinois mineral industry for 1951 is being prepared for publication. This work is carried on with the cooperation of the U. S. Bureau of Mines, the U. S. Bureau of the Census, and the State Department of Mines and Minerals. Similar annual reports issued since 1931 constitute an uninterrupted series on Illinois mineral industry since that date.

Topographic Mapping

55. *Topographic maps for more than 90 per cent of the State's area* have now been prepared as the result of a systematic program of mapping which is carried forward each year in cooperation with the U. S. Geological Survey. Through the progressive attitude of Illinois legislators in regularly appropriating funds to carry on this work (funds so appropriated are matched dollar for dollar by the Federal Government), this ambitious and very important task is nearing completion. If appropriations sufficient to maintain the current rate of mapping are continued, the original topographic mapping of the entire area of the State will be completed in five years.

During the past year, 702 square miles of territory, including 94 square miles of revision, were mapped topographically in the field on a scale of one inch to a mile, and planimetric maps to serve as bases for topographic mapping were made for all or portions of four quadrangles, all on the cooperative basis. In addition, the U. S. Geological Survey with non-cooperative Federal funds mapped one quadrangle (about 225 square miles) and parts of two others on a scale of one inch to a mile.

Two new quadrangle maps on a scale of one inch to a mile, 10 new quadrangle maps on a scale of 2½ inches to a mile, one remapped

quadrangle map on a scale of 2½ inches to a mile, and reprints of one quadrangle map on a scale of ½ inch to a mile and of 5 quadrangle maps on a scale of one inch to a mile were published by the U. S. Geological Survey during the past year from this cooperative work.

Public Service and Educational Extension

56. *Public information.* One of the major obligations of the State Geological Survey is to furnish accurate information to the citizens of the State. Scrupulous and prompt attention is given to every inquiry received whether it be from a pupil in the school, from a Boy Scout working on a merit badge, or from a large industrial corporation. Thousands of requests are received every year and each one is handled by the staff member best equipped to furnish the information desired. The Survey's files contain hundreds of letters from individual citizens, from mineral operators, school teachers, chambers of commerce, village and city councils, and large industrial organizations expressing sincere appreciation of the prompt and courteous service received from their State Geological Survey. These letters are in themselves rich reward for the pains taken.

57. *Educational extension.* For the past 23 years a special division of the Geological Survey has been rendering educational extension service throughout the State. This service includes free identification of mineral specimens; informative correspondence with teachers and citizens; free lectures to organized groups; publication of popular educational pamphlets; the distribution of free rock-and-mineral collections to schools, the organization and leadership of field study conferences for science teachers; and educational exhibits at State and County fairs and special scientific meetings. Every effort is made to assist the science teachers of the secondary and even primary schools of the State in the fine work they are doing in the technical and cultural education of our young people.

During the past year 302 sets of typical rocks and minerals were distributed to schools, scout troops, nature clubs, and other civic organizations throughout the State.

Field conferences primarily designed for science teachers but open to all interested persons were held in 6 widely separated areas. Mimeographed guide leaflets are prepared for each trip and there are now some 35 such reports available to teachers, students, and citizens.

Ten special lectures were given to conservation workshops, to local nature study clubs, and professional societies.

RESEARCH FACILITIES

The physical facilities of the Survey for research on mineral resources are probably not excelled in any comparable institution. The following is a summary of the laboratories:

Geological Resources Section

Five laboratories for coal research: one in mining geology for mine roof studies, diamond drill core studies, and studies of coal resources in Illinois; one coal petrography laboratory for megascopic and microscopic studies of thin sections of coal, polished surfaces of coal, character of broken coal, characteristics of coals of various ranks, and examinations of prepared coal; two for paleobotanical research, including preparation of samples for study, studies of the botanical constituents of coal, content and characteristics of fossil spores occurring in coal, and character of the banded ingredients of Illinois coals; and one for the study of samples from strata associated with coal and the preparation of coal-resources and related maps.

One laboratory for petroleum engineering research, now chiefly for studies of fluid flow through porous media and related problems.

Four laboratories for fundamental research on industrial minerals: one molding-sand laboratory for testing molding sands and clays for bonding molding sands; one for fundamental research on the basic mineralogy of dolomites and limestones; one for studies of the character, composition, and uses of limestone, dolomite, sand, gravel, silica, and other industrial minerals; and one for the microscopic study of zinc, lead, and fluorspar ores and of limestone, dolomite, and other industrial minerals.

Four laboratories for research on clays and clay mineral technology: two primarily for differential thermal analyses of clays and related materials; and two for testing the physical properties of clays in relation to soil mechanics, ceramic utilization, recovery of petroleum, and other engineering problems.

One laboratory for research on geophysical equipment, including apparatus for electrical resistivity surveys, radio transmission through geological formations, seismic surveys, and the electric logging of wells; also used for research on materials pertaining to groundwater geology, consisting mainly of mechanical analyses of samples from water wells and the study of drill cuttings from water wells.

Three laboratories for research in stratigraphy and areal geology: one subsurface-geology laboratory for the study of samples of drill cuttings from water and oil wells, diamond drill cores obtained in test drilling for oil and gas and other geological information, the prepara-

tion and study of insoluble residues obtained from well cuttings, drill cores, and rock samples, and the examination of well samples by visiting petroleum and other field geologists; one laboratory for the study of diamond drill cores, insoluble residues, mechanical analyses, and heavy minerals; and one laboratory for paleontologic research involving the identification of fossils and their use in the identification and correlation of strata throughout the State.

Three rooms are equipped with apparatus used in the preparation of industrial minerals, rocks, diamond drill cores, and well cuttings for research studies.

Geochemical Section

Five analytical laboratories: one devoted to analysis and determination of heat value of coal purchased by the institutions of the State; one for analysis of coal, coke, and char in research on Illinois coals; one for analysis of rocks and brines; one for the study of oil sands and composition and properties of petroleum, natural gas, and petroleum products; and one for determination of nitrogen in connection with coal analysis.

One microanalytical laboratory for rapid analysis of materials when very small samples are used.

Two research laboratories for the fundamental study of the chemical nature of coal.

Three laboratories for the study of the physical and chemical properties of silicate materials at high temperature, surface properties of coal, coke, and char, and factors that affect efflorescent coating of building brick.

Two laboratories devoted to the study of organic fluorine compounds derived from fluorspar, deposits of which, in southern Illinois, are unique and rank first in production in the Western Hemisphere.

One X-ray laboratory for mineral identification and for study of atomic and molecular structure of minerals.

Three spectrographic laboratories for determining constituents present in trace amounts in minerals and rocks, including petroleum and petroleum products, coal, liquefied coal products, and new laboratory compounds.

One laboratory equipped with two armored cubicles in which experiments requiring special precaution from explosion are carried out.

One research laboratory for developing improved methods of analysis of naturally occurring mineral resources of Illinois.

One furnace room with electric and gas furnaces for ashing of coals, stabilization of precipitates in analytical work, investigation of chemical changes that take place in rocks and minerals when treated at various temperatures, and for the study of other temperature phenomena.

Two rooms for the preparation and drying of coal samples for analysis.

One small shop room equipped for use by the laboratory staff.

Experimental Laboratory Building

A special laboratory building, built in 1941, located near the University Power Plant, is used for the study on semi-pilot plant scale of coke and char potentialities of Illinois coal and of the combustion characteristics of Illinois stoker coal. This building also has a small machine shop for work in connection with maintenance and adjustment of research equipment in the building.

Machine Shop

The Survey possesses a specially equipped machine shop in the Natural Resources Garage for the design and construction of research apparatus not available on the open market. The equipment includes one No. 2 milling machine, one modern lathe for moderately heavy work, one small lathe for light work, four drill presses of assorted sizes, and other accessory apparatus for the construction of instruments and specialized research apparatus.

Modern Research Apparatus

The equipment of the Survey's research laboratories includes, among other things, certain distinctive and specialized items, such as high-powered microscopes, X-ray, spectrographs, geiger counters, high-pressure equipment, photoelectric potentiometers, infra-red spectrophotometer, electronic photometer and photomultiplier, graphic recorders, refraction seismic equipment, earth resistivity equipment, special instruments for the study of radio wave transmission through geological formations, differential thermal analysis units, low-temperature fractional gas distillation equipment, extrusion machine, apparatus for measuring gas absorption on solids, heat-of-wetting equipment, liquid limit machine, moisture testers, penetrometers, refractometers, roll pulverizers, surface tension equipment, ultrasonic generators, viscosimeters, well depth measuring equipment, and many other unusual devices for obtaining important factual information on the mineral resources of the State.

ADMINISTRATIVE SCIENTIFIC AND TECHNICAL PERSONNEL

The key to creative research is the scientist. Careful attention has been given to the selection of research personnel to meet the high scientific standards of the Survey. Space does not permit the listing of all the scientific personnel of the State Geological Survey but there is given below the administrative scientific and technical personnel who direct the research program and public service of the Survey.

Office of the Chief

M. M. Leighton, Chief; B.S., U. of Iowa, 1912, M.S., 1913; Ph.D., U. of Chicago, 1916. Faculty member of State U. of Wash., 1915-16; U. of Chicago, summer 1916; Iowa State Teachers College, 1916-17; State U. of Wash. (also Washington Geological Survey), 1917-18; Ohio State U., 1918-19; U. of Illinois (also State Geological Survey), 1919-23; Member of Ill. State Museum Board, 1937-; Vice Chairman Post-War Planning Commission, 1945-47; Member Advisory Committee to U. S. Geol. Survey, 1943-; Chief, Ill. State Geol. Survey, 1923-.

Enid Townley, Geologist and Assistant to the Chief; B.S., U. of Chicago, 1921, M.S., 1925. Midwest Refining Co., 1922; staff, Wellesley College, 1922-24; Guide Lecturer, Chicago Academy of Sciences, 1926-27; Geologist, Pure Oil Co., 1927-31; Geologist and Assistant to the Chief, Ill. State Geol. Survey, 1931-.

Gilbert O. Raasch, Geologist in Charge, Educational Extension; B.A., U. of Wisconsin, 1929, Ph.D., 1946. Curator, Wis. Geological Museum, 1929-36; Magnolia Petroleum Corp., 1936-37; Darby Petrol, 1937-38; Milwaukee Public Museum, 1940-42; Major, Air Force, 1942-46; Ill. State Geol. Survey, 1946-.

Anne E. Kovanda, Librarian; B.S., U. of Ill., 1937, B.L.S., 1942. Staff, U. of Ill. Journalism Library, 1941-42; Detroit Public Library, Technology Department, 1942-1947; Ill. State Geol. Survey, 1947-.

Vivian Gordon, Head, Mineral Resource Records; Skelly Oil Co., 1937-42, Exec. Sec., Land and Production Dept., Globe Oil and Refining Co., 1942-46; Ill. State Geol. Survey, 1946-.

Jane V. Olson, Associate Technical Editor; B.A., U. of New Mexico, 1939. Staff Museum of New Mexico, 1939-40; Commerce Clearing House, 1941; Peabody Museum, Harvard U., 1942-43; Atlantic Monthly Co., 1943-46; Condé Nast Publications, Inc., 1946-49; Ill. State Geol. Survey, 1949-.

Geological Resources Section

Arthur Bevan, Principal Geologist in Charge of Geological Resources Section, and Acting Head of Coal Division; B.S., Ohio Wesleyan U., 1912, Sc.D., 1942; Ph.D., U. of Chicago, 1921. Faculty member, Ohio Wesleyan U., 1912-14 (acting Head Dept. of Geol. 1913-14); Ohio State U., 1917-19; State U. of Mont., 1919-21 (also Montana Bureau of Mines, summers 1919-22); U. of Ill., 1921-29; U. of Chicago, summer 1924; Ill. State Geol. Survey, summers 1923-29; State Geologist of Virginia, 1929-47; Chairman, Division of Geology and Geography, National Research Council, 1946-49; Principal Geologist, Ill. State Geol. Survey, 1947-.

A. H. Bell, Geologist and Head of Oil and Gas Division; B.A., U. of Toronto, 1917; Ph.D., U. of Chicago, 1926. Scholar, National Research Council of Canada, 1920-21; Geological Survey of Canada, 1914, 1920-23; Texas Co., 1924-26; Ill. State Geol. Survey, 1926-.

Paul A. Witherspoon, Petroleum Engineer and Head of Petroleum Engineering Division; B.S., U. of Pittsburgh, 1941; M.S., U. of Kansas, 1951. Phillips Petroleum Co., 1941-49; U. of Kansas, 1949-1951; Ill. State Geol. Survey, 1951-.

J. E. Lamar, Geologist and Head, Industrial Minerals Division; B.S., U. of Chicago, 1920. Ill. State Geol. Survey, 1920-.

Ralph E. Grim, Consulting Clay Mineralogist; Ph.B., Yale U., 1924; Ph.D., U. of Iowa, 1931. Staff, U. of Miss. and Miss. Geol. Survey, 1926-30; U. of Iowa, 1930-31; Ill. State Geol. Survey, 1931-50; U. of Ill., 1950-.

Frank C. Foley, Geologist and Head of Groundwater Geology and Geophysical Exploration; B.A., U. of Toronto, 1929; Ph.D., Princeton U., 1938. Staff, Dartmouth College, 1929-30; Princeton U., 1930-33; U. of North Dakota, 1933-41; State Geologist, North Dakota Geological Survey, 1938-41; U. S. Geol. Survey, 1941-42 and 1946-51; Major, Corps of Engineers, 1942-45; Ill. State Geol. Survey and U. of Ill., 1951-.

M. Wm. Pullen, Geologist and Head, Geophysical Research; B.A., Colgate U., 1938; M.S., Syracuse U., 1940; Ph.D., U. of Ill., 1950. Cunningham Oil Co., summers 1937, 1938. Staff, Syracuse U., 1938-40; U. of Ill., 1940-42; Ill. State Geol. Survey, 1942-.

George E. Ekblaw, Geologist and Head, Engineering Geology and Topographic Mapping; A.B., U. of Ill., 1922, A.M., 1923; Ph.D., Stanford U., 1927. Ill. State Geol. Survey, 1920-25; 1927-.

H. B. Willman, Geologist and Head, Stratigraphy and Areal Geology; A.B., U. of Ill. 1926, M.A., 1928, Ph.D., 1931. Kentucky Geol. Survey, 1926; staff, U. of Ill., 1926-28; Ill. State Geol. Survey, 1927-.

Geochemistry Section

Frank H. Reed, Chief Chemist; A.B., Wabash College, 1911; Ph.D., U. of Chicago, 1917. Staff, Wabash College, 1913-14; Mich. State College, 1914-15; Sherwin-Williams Co., 1917-19; Butterworth-Judson Corp., 1919-22; Supt., Chemical Plant, Tower Manufacturing Company, 1922-27; Chemical Dye & Mfg. Co., 1927-28; Plant Supervisor, National Aniline & Chemical Co., 1928-30; Roessler & Hoslacher Chemical Co., 1930-31; Scientific Consultant, Federal Economic Administration, Northwest Europe, 1945; Visiting expert to General MacArthur's Headquarters, Tokyo, December 1948-February 1949; Ill. State Geol. Survey, 1931-.

G. R. Yohe, Chemist and Head, Coal Chemistry, B.A., Cornell College, 1925; M.S., U. of Ill., 1927, Ph.D., 1929. Goodyear Tire and Rubber Co., 1929-30; staff, Ohio Wesleyan U., 1930-37; Ill. State Geol. Survey, 1937-.

J. S. Machin, Chemist and Head, Physical Chemistry; A.B., Westminster College (Mo.), 1921; M.S., U. of Ill., 1922; Ph.D., U. of Chicago, 1932. Staff, Westminster College, 1922-24; Sioux Falls College, 1924-36; Ill. State Geol. Survey, 1936-.

G. C. Finger, Chemist and Head, Fluorine Chemistry; B.S., U. of Ill., 1927, M.S., 1928, Ph.D., 1938. Staff, Purdue U., 1928-30; U. of Ill., 1930-32; Ill. State Geol. Survey, 1933-.

H. W. Jackman, Chemical Engineer and Head, Chemical Engineering; B.S.E., U. of Mich., 1923, M.S.E., 1924. Champion Spark Plug Co., 1924-25; Chief Chemist and Supt. of Manufacture, Battle Creek Gas Co., 1925-41; Ill. State Geol. Survey, 1942-.

W. F. Bradley, Chemist and Head, X-ray Division; A.B., U. of Ill., 1930; Ph. D., 1935. Ill. State Geol. Survey, 1934-.

Kenneth B. Thomson, Physicist; B.A., U. of Western Ontario, 1923, M.A., 1924; Ph.D., U. of Mich., 1932. Alderson, Mackay & Armstrong, 1927-28; staff, Queens U. (Ontario), 1928-30; U. of Mich., 1930-31; Queens U., 1932-33; Cancer Research Lab., U. of Penna., 1933-34; U. of Mich. (Rockefeller Foundation Grant), 1934-36; National Smelting Co., 1937-48; National Spectrographic Laboratories, 1948; Ill. State Geol. Survey, 1949-.

O. W. Rees, Chemist and Head, Analytical Chemistry; B.S., Earlham College, 1922; M.S., U. of Ill., 1925, Ph.D., 1931. Staff, Earlham College, 1922-24; Ill. State Water Survey, 1925-30; Ill. State Geol. Survey, 1931-.

Mineral Economics

W. H. Voskuil, Mineral Economist; B.S., U. of Wis., 1921, M.S., 1922, Ph.D., 1924. Staff, U. of Wis., 1922-24; Wharton School of Finance, U. of Penna., 1924-30; Chief Mineral Economist, National Industrial Conference Board, 1930-31; Mineral Economist, U. S. Bureau of Mines, 1931; Consultant, Office of Price Administration, 1941-42; Council of Foreign Relations, 1943; Ill. State Geol. Survey, 1931-. and U. of Ill., 1949-.

In the Geological Resources Section, the full-time staff of the Coal Division numbers 12; Oil and Gas, 8; Petroleum Engineering, 2; Industrial Minerals, 5; Clay Resources and Clay Mineral Technology, 3; Groundwater Geology and Geophysical Exploration, 7; Geophysical Research, 3; Engineering Geology, 1; and Stratigraphy and Areal Geology, 10.

In the Geochemistry Section, the full-time staff of the Division of Coal Chemistry numbers 3; Physical Chemistry, 3; Fluorine Chemistry, 3; Chemical Engineering, 6; X-ray, 1; Spectrochemistry, 2; and Analytical Chemistry, 13.

The staff of Mineral Economics includes three persons.

The Survey has 8 research affiliates and 6 consultants, most of whom are faculty members of the University of Chicago, University of Illinois, Northwestern University, and University of Southern Illinois.

The Library staff includes 3, Mineral Resource Records Division, 8, and Editing and Publications, 4. An additional 26 persons handle stenographic service, correspondence files, office information, financial records, mailing service, machine shop work, and maintenance of motor vehicles.

Twenty-two college students, most of them specializing in geology, are employed part-time as research and technical assistants.

Publications

Prompt publication of results obtained from research work is essential to its greatest effectiveness. Every effort is made by the Survey to bring its information to the citizens of the State as soon as possible consistent with accuracy.

Publications issued during the year include the following:

Bulletin:

76. Geology of the Fluorspar Deposits of Illinois: J. Marvin Weller, Robert M. Grogan, and Frank E. Tippie. 1952. 147 pp., 25 figs., 7 pls., 4 tables. General geology of the Illinois fluorspar district; history, production, and uses of fluorspar; mining, milling, and prospecting methods.

Reports of Investigations:

151. Correlation of Domestic Stoker Combustion with Laboratory Tests and Types of Fuels. IV. Combustion Tests of Illinois and Other Coals: Roy J. Helfinstine. 1951. 46 pp., 30 figs., 13 tables.
Tests show that Illinois coals rank high as domestic stoker coals.

152. The Mississippian-Pennsylvanian Unconformity in Southern Illinois: Raymond Siever. 1951. (Reprinted from Bull. Am. Assoc. Petr. Geol., vol. 35, no. 3, pp. 542-581, March 1951.) 40 pp., 13 figs.
A systematic study of the structure and geologic history of the unconformity.

153. Subsurface Geology and Coal Resources of the Pennsylvanian System in White County, Illinois: John A. Harrison. 1951. 40 pp., 15 figs., 3 pls., 4 tables.
Includes structure maps of West Franklin limestone and Herrin (No. 6) coal bed.

155. An Integrated Geophysical and Geological Investigation of Aquifers in Glacial Drift Near Champaign-Urbana, Illinois: John W. Foster and Merlyn B. Buhle. 1951. (Reprinted from Economic Geology, vol. 46, no. 4, pp. 367-397, June-July 1951.) 31 pp., 14 figs.
For the purpose of efficient development of groundwater resources for public, industrial, and domestic use throughout this 300-square-mile area.

156. Geology and Coal Resources of a Part of the Pennsylvanian System in Shelby, Moultrie, and Portions of Effingham and Fayette Counties: Ernest P. Du Bois. 1952. 32 pp., 9 figs., 5 pls.
Includes structure maps of Millersville limestone, Coal No. 7, Coal No. 6, and Coal No. 4.

157. An Economic Study of Fuels in Manufacturing: Walter H. Voskuil. 1952. (Published in cooperation with the Engineering Experiment Station, University of Illinois.) 28 pp., 26 tables.
Amount and kind of fuels used by industries; the role of electric power; comparative fuel costs.

158. Illinois Mineral Industry in 1950: Walter H. Voskuil. 1952. 58 pp., 19 figs., 46 tables.
Annual statistical summary and economic review.

159. Pleistocene Geology of the Danville Region: Harmon E. Eveland. 1952. 32 pp., 14 figs., 1 pl.
Treats of the glacial deposits and the buried bedrock surface of the area.

160. Waltersburg Sandstone Oil Pools of Lower Wabash Area, Illinois and Indiana: David H. Swann. 1952. (Reprinted from Bull. Am. Assoc. Petr. Geol., vol. 35, no. 12, pp. 2561-2581, December 1951.) 21 pp., 13 figs.
Discusses diverse structures of Waltersburg sandstone in which oil is found.

161. Preliminary Report on the Variations in Differential Thermal Curves of Low-Iron Dolomites: Donald L. Graf. 1952. (Reprinted from The American Mineralogist, vol. 37, pp. 1-27, 1952.) 27 pp., 8 figs., 3 tables.
Soluble salts are shown to be a major cause of variations in thermal curves of some low-iron dolomites.

Illinois Petroleum Series:

63. Developments in Illinois and Indiana in 1950: A. H. Bell and R. C. Cooper. 1951. (Reprinted from Bull. Am. Assoc. Petr. Geol., vol. 35, no. 6, pp. 1206-1218, June 1951.) 13 pp., 1 fig., 11 tables.

64. Oil and Gas Development in Illinois During 1950: A. H. Bell, Virginia Kline, and David H. Swann. 1952. (Reprinted from Statistics of Oil and Gas Development and Production Covering 1950, Am. Inst. Min. Met. Eng.) 46 pp., 7 figs., 8 tables.

Circulars:

172. Mineral Resource Research and Activities of the State Geological Survey, 1949-1950: M. M. Leighton. 1951. (Reprinted from the Ann. Rept. Dept. of Reg. and Ed. for Fiscal Year 1949-50.) 28 pp., illus.
Describes the activities in various fields of the State Geological Survey for the fiscal year July 1, 1949, to June 30, 1950.

174. Natural Resources and Geological Surveys: M. M. Leighton. 1951. (Reprinted from Economic Geology, vol. 46, no. 6, pp. 563-577, Sept.-Oct. 1951.) 15 pp., 1 fig.
History of the growth of state geological surveys in relation to the development of natural resources.

175. Mineral Resource Research and Activities of the State Geological Survey, 1950-1951: M. M. Leighton. 1952. (Reprinted from the Ann. Rept. of Dept. of Reg. and Ed. for Fiscal Year 1950-1951.) 38 pp., illus.
Describes the various activities of the State Geological Survey for the fiscal year July 1, 1950, to June 30, 1951.

176. Summary of Water-Flooding Operations in Illinois Oil Pools to 1951: Frederick Squires et al. 1950. (Reprinted from the Report Published by the Interstate Oil Compact Commission, 1951.) 42 pp., 27 figs.
Summarizes the important work accomplished by the Secondary Recovery Study Committee for Illinois of the Interstate Oil Compact Commission.

177. Market Outlook for Sulfur Recoverable from Coal: Walter H. Voskuil. 1952. (Reprinted from Ill. Min. Inst. Pros., 1951.) 23 pp., 7 tables.
Discusses coal as a source of sulfur to supplement the inadequate native sulfur resources.

178. Some Observations on the Blending of Coals for Metallurgical Coke: F. H. Reed, H. W. Jackman, O. W. Rees, and P. W. Henline. 1952. (Reprinted from Blast Furnace and Steel Plant, vol. 40, no. 3, pp. 305-311, 314, March 1952.) 8 pp., 3 figs., 7 tables.
Shows the economic advantages of substituting up to 50% Illinois coals for a like percentage of Eastern high-volatile coals in the production of metallurgical coke in the Chicago district.

179. Short Papers on Geologic Subjects: J. W. Foster, J. E. Lamar and R. R. Reynolds, H. B. Willman and J. S. Templeton, R. S. Shrode, and G. O. Raasch. 1952. (Reprinted from Trans. Ill. Acad. Sci., vol. 44, 1951.) 59 pp., 26 figs.
Five papers on aspects of Illinois geology which were presented at the 1951 meeting of the Illinois Academy of Science.

180. Some Important Aspects of Water Flooding in Illinois: Paul A. Witherspoon. 1952. (Preprint of paper presented Spring Meeting of Eastern

District, Div. of Prod., Am. Petr. Inst., Pittsburgh, April 4, 1952.) 14 pp., 11 figs.

History and recent developments of water flooding as a means of secondary recovery of Illinois oil.

Educational Series:

3. Typical Rocks and Minerals in Illinois: G. E. Ekblaw and D. L. Carroll. Fifth revision, 1951. 79 pp., 42 figs., glossary.

Miscellaneous:

Oil and Gas Drilling Report, mimeographed, issued monthly.
Supplementary Book of Charts for monthly Oil and Gas Drilling Report. 1951.

The Board of Natural Resources and Conservation

BOARD OF NATURAL RESOURCES AND CONSERVATION

Honorable C. Hobart Engle, Chairman

Ex-Officio Members—
George D. Stoddard, President University of Illinois
Delyte W. Morris, President, Southern Illinois University

Biology—A. E. Emerson, University of Chicago

Chemistry—Roger Adams, University of Illinois

Engineering—Louis R. Howson, Chicago

Forestry—Lewis H. Tiffany, Northwestern University, Vice President and Secretary of the Board

Geology—W. H. Newhouse, University of Chicago

The Board of Natural Resources and Conservation, which directs and controls the work of the Geological Survey, the Natural History Survey, and the Water Survey, was created by the Civil Administrative Code in 1917. It is composed of distinguished scientists, each qualified by at least ten years professional experience in his special field, as shown above, and functions under the ex-officio chairmanship of the Director of the State Department of Registration and Education.

Under the law this Board selects and appoints, without reference to the State Civil Service law, all members of the technical staffs and approves the budgets and programs of the three scientific surveys. The Board is traditionally nonpartisan and its members serve without pay. Membership is by appointment of the Governor, and it is a standing tribute to the broad vision of our State administration and to the abilities of the Board members that since the Board's inception, changes on the Board have been made only upon the death or retirement of a member. Because several sciences, four different universities, and industry are represented by the Board membership, its points of view are collectively sufficiently broad to insure general representation of the interests of the State.

The Board, which meets at regular intervals, receives and carefully studies quarterly reports from the three chiefs of the scientific surveys. It acts in an advisory capacity over the manifold research and activities of the three surveys which are concerned with aiding in the development of and augmenting the natural resources of the State. The devotion of Board members to the responsibllities imposed upon them by law, their recognition of measures consistent with sound public policy, their comprehension of fruitful research programs, and their exercise of great care in selection of scientific staffs have resulted in national and international recognition of Illinois and its wealth of natural resources.

Recent outstanding capital improvements to the physical facilities of all three Surveys received the unqualified approval of the Board

before they were submitted for the consideration of State authorities and the Legislature. Although the scientific surveys are administered by the State Department of Registration and Education, location of the surveys' headquarters and principal laboratories on the University of Illinois campus at Urbana offers many advantages. Research is furthered through the availability of the University's libraries and some of the laboratories and experimental field-plots, and in like manner survey facilities are made available to University staff members and some advanced students seeking professional training. Cordial relations and a generous exchange of information between University and survey staffs make for prompt and effective dissemination of the results of research. Operational economy is also achieved by one system, maintained by the University, that provides water, heat, light and other services for the surveys and the University.

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